JAN 2 1925

MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

Happy New Year

The American Society of Mechanical Engineers has just completed a most successful year, marked by the adoption of a sound financial policy and with an ever-increasing volume of technical achievement and now brought to a conclusion by one of the best Annual Meetings ever held. The growth of engineering influence in society at large and the ever-broadening problems of industry bring a constantly increasing opportunity for the individual engineer and for the profession at large to recognize and to assume larger responsibilities in the progress of civilization and in the advance of the public weal.

The officers of the Society hope that these enlarging opportunities will be welcomed as occasions for the discharge of a definite personal obligation and in expressing appreciation for the good work done during the past year, they extend their hearty wishes to the membership for a successful and happy New Year.

W. F. Durand, *President*

(The American Society of Mechanical Engineers)

JANUARY 1925

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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Its broad scope is shown by the following typical examples:

1. **Product Service.** Linde engineers discovered how to produce pure oxygen in volume and at low cost. They developed the Linde Type K cylinder which replaced clumsy containers of small capacity. This cylinder is now the accepted standard in the entire industry. Linde engineers also found why valves leaked and built one that wouldn't.
2. **Distribution Service.** Linde executives saw why one big central plant would not insure a supply and how a national chain of plants and warehouses would give each user a dependable and convenient supply with low freight cost. Linde transportation engineers saw the opportunity for truck delivery and planned a trucking service that is always on time.
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Mechanical Engineering

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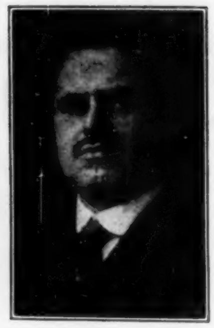
L. J. Franklin

H. L. Wirt

D. F. Davis

J. D. Sears



H. Kreisinger

C. H. Smith

Contributors to this Issue

Fred R. Low, whose presidential address before The American Society of Mechanical Engineers is the leading article in this issue, has been editor of *Power* since 1888. In thirty-six years of service in this capacity he has attained distinction not only as an editor but as an authority on power-plant subjects. He is an honorary member of the Institution of Mechanical Engineers (British) and a Doctor of Engineering, Renssalaer, 1924. Mr. Low has been a member of the A.S.M.E. since 1886, serving as president during the past year.

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Julian D. Sears, who writes on Engineers and the American Petroleum Situation, is administrative geologist of the U. S. Geological Survey. Mr. Sears is a graduate of Johns Hopkins University, class of 1913. He received his Ph.D. in 1919. Except for two years spent in Costa Rica and Panama for the Sinclair Central American Oil Corporation, he has been with the Survey since 1915, where he has carried on investigations of the geology of petroleum, gas, and coal lands in the Rocky Mountain States.

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H. Loring Wirt, author of The Turbine Designer's Wind Tunnel, was graduated from the Massachusetts Institute of Technology in 1918 with a B.S. degree in naval architecture and marine engineering. During the war he was a lieutenant in the Engineers Corps, U. S. A., serving overseas. He entered the employ of the General Electric Co. in 1920, and since then has been in the turbine-engineering department, doing experimental research work, principally on the flow of elastic fluids.

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Henry Kreisinger, research engineer with the Combustion Engineering Corporation of New York since 1920, is the author of A Review of Recent Applications of Powdered Coal to Steam Boilers. He is a graduate of the University of Illinois with the degrees of B.S. and M.E. From 1906 to 1910 Mr. Kreisinger worked with Professor Breckinridge of Yale on fuel tests conducted by the U. S. Geological Survey. For three years he was associated with the Clinchfield Fuel Co., and then for seven years was in charge of fuel investigations with the U. S. Bureau of Mines.

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Ray C. Burrus, who writes on The Diesel Engine in Small and Medium-Sized Power Plants, was graduated from Massachusetts Institute of Technology in 1922 with the degree of B.S., and since that time has been sales engineer in the Diesel engine division of the Fulton Iron Works, St. Louis, Mo.

* * * * *

John Wolff, mechanical engineer with the Cleveland Electric Illuminating Co., is the author of Test of Pulverized-Fuel-Fired Boilers at the Lake Shore Station, Cleveland. He was graduated from Stevens Institute of Technology in 1888, and was for ten years with the Edison Electric Light Co. in Brooklyn, N. Y., and for two years with the Mahoming Valley Railway in Youngstown, Ohio, as chief engineer. Since 1905 Mr. Wolff has been connected with the Cleveland Electric Illuminating Co.

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L. J. Franklin and **C. H. Smith,** coauthors of The Effect of Inaccuracy of Spacing on the Strength of Gear Teeth, are respectively draftsman with the San Bernardino Ice & Precooling Plant, San Bernardino, Cal., and instructor in mechanical engineering, Stanford University. Both Mr. Franklin and Mr. Smith were graduated from Stanford University in 1923 with the degrees of A.B., receiving their M.E. degrees the following year.

* * * * *

Dwight F. Davis, Assistant Secretary of War, the author of Engineering Problems of National Defense, is charged with the supervision of the procurement of all military supplies and the assurance of adequate provision for the mobilization of industrial organizations essential to wartime needs. He entered the Army in 1917 as a captain of infantry and served throughout the War, being discharged in 1919 with the commission of lieutenant-colonel. He was a director of the War Finance Corporation in 1921.

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Lewis A. DeBlois, whose address on A Place for Safety is included in this issue, is manager of the Safety Division of E. I. DuPont de Nemours & Co. He is a past president of the National Safety Council.

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L. B. Tuckerman, author of Hardness and Hardness Testing, received the degree of A.B. in 1901 from Western Reserve University, later taking graduate work in physics at the Universities of Nebraska and Berlin (Germany), and at Johns Hopkins University, from which latter he received the degree Ph.D. He taught physics at the University of Nebraska for 13 years, becoming professor of theoretical physics in 1912. In 1918 he became associated with the Bureau of Standards where he has since been engaged in investigations of engineering problems, particularly the relation of the properties of materials to their use in engineering structures.

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Earle Buckingham, engineer with the Pratt & Whitney Co., Hartford, Conn., writes on Inspection Methods. During his career he has been associated as draftsman with the American Graphophone Co., the Veeder Manufacturing Co., and the Royal Typewriter Co. During the war he served as captain in the engineering division of the Ordnance Department of the Army.

The Forty-Fifth A.S.M.E. Annual Meeting

Over twenty-one hundred members and guests attended the Annual Meeting held in New York, December 1 to 4, 1924, taking part in the many technical sessions and social events arranged for the week. A running account of the meeting will be found in this issue. The current issues of the A.S.M.E. News carry the details of the social activities.

MECHANICAL ENGINEERING

Volume 47 January, 1925 No. 1

Power Resources, Present and Prospective

By Fred R. Low, New York, N. Y.

At a recent gathering of engineers and scientists one of the speakers quoted Bagehot to the effect that during the early ages of civilization slavery was essential to progress because only through the enforced labor of the many could the few find time to think.

It is within only comparatively recent times that the burden of supporting the race, the drudgery of the struggle for existence, has been transferred to power-operated machinery.

Up to the nineteenth century man was largely dependent upon the work of his own muscles and those of the animals that he had domesticated for his sustenance, shelter, and transportation. His only help from natural resources was in crude adaptations of water and wind power.

Today power-operated machinery is doing in these United States alone more work than could be performed by all the able-bodied men in the world working like slaves from sunrise to sunset.

In a century we have come to be dependent upon our supply of artificial power to such an extent that any interruption of or serious diminution in it would mean industrial and social chaos, a relinquishment of much of the comfort and convenience and culture of our present civilization, and a serious retrogression in the progress of the race.

It may not be uninteresting, therefore, or irrelevant to the occasion to take account of the power resources at our command and the increasing rate at which we are drawing upon them, to pass in review the various processes by which these resources are converted, to see how nearly we have come to ultimate efficiencies, to glance in the direction of possible improvements, and to speculate on other sources of power which research may disclose before our unrenewable supplies of fuel are depleted.

Underwood & Underwood

Fred R. Low

The least important factor in the direct production of power is the wind, although in its propulsion of sailing vessels and the operation of a multitude of windmills, large and small—principally small—the power that it furnishes must be, in the aggregate, considerable. The wind is, however, an important factor in carrying the water that has been evaporated from the oceans in the form of clouds and moisture-laden air across the continents and depositing it upon the mountains and highlands, endowed with the power to generate in its descent energy equivalent to that consumed in its elevation. As the evaporation is effected by heat and the movement of the winds is due to differences of temperature, both of these forms of power are, in the last analysis, manifestations of heat energy.

The natural application of running water to the turning of a wheel by weight or impact led to simple reaction types and eventually to the turbine.

The possibility of generating considerable amounts of power by the use of this compact prime mover made possible the development of sizable industries, and the establishment of these industries upon rivers where hydraulic power in the required amounts was producible, was the determining factor in the location of many cities and manufacturing districts.

Power has thus played an important role in determining the geographical distribution of industry, the occupation and manner of livelihood of whole sections, the attraction to certain localities of different classes of population, and the parts that different divisions of the country play in our social economy.

It will be interesting when some historian, sufficiently removed in point of time to have the right perspective, evaluates the effect of invention and engineering, rather than of conquest and politics, upon the development of this nation. What differences would there have been in our local characteristics and industrial set-up if, in the beginning electrical distribution had made it unnecessary to locate the factory at the dam and had made profitable the development of water powers then too inaccessible or remote from established demand?

At the time of the organization of this Society the most powerful turbine in existence had a capacity of only a few hundred horsepower, and usual efficiencies were below 70 per cent.

There are now in operation at Niagara three units of 70,000 horsepower each, capable of converting over 90 per cent of the energy of the water passing through them into useful work.

Various authorities estimate the work that a man turning a winch is capable of doing as from 1,250,000 to 2,500,000 foot-pounds per day—and these estimates were made when a day's work was more than eight hours. Taking it at 2,000,000 foot-pounds per day, each 70,000-horsepower turbine, which can work 24 hours a day at full load if it has to, can do the work of more than 1,633,000 men.

Working 24 hours a day at full load for a year, it would develop as much power as would over 600,000 tons of coal at only two pounds per horsepower-hour.

This is more than one-thousandth of all the coal that we mine, and more than one six-hundredth of all the coal that is burned for power production.

This estimate may be modified by a very moderate use factor and still leave a significant figure.

Power Resources of the Country and the Increasing Rate at Which They are Being Drawn Upon

The potential water-power resources of the United States are estimated by the Geological Survey at, in round numbers, 34,000,000 horsepower available 90 per cent of the time and 55,000,000 available 50 per cent of the time.

The total amount of power used, or even of the prime-mover

Presidential Address at the Annual Meeting, New York, December 1 to 4, 1924, of The American Society of Mechanical Engineers.

capacity installed, in the country is impossible of close estimate. A survey made jointly by the *Electrical World* and *Power* shows that there are installed in the mills and factories of the United States some 34,000,000 horsepower, and in the central electric stations, 24,600,000 horsepower. There is some duplication on account of the fact that the industrial-plant figure includes motors, current to drive which is purchased from the central station. The combined installed capacity of prime movers may be guessed at as about 45,000,000 horsepower.

	Installed Capacity, Hp.
Central stations and industrial	45,000,000
Electric railways (Jan. 1, 1923)	4,119,000
Mining (Jan., 1920)	5,147,000
Stationary, non-industrial	4,000,000
Steam railroads	130,000,000
Navigation	16,000,000
Agricultural and traction	200,000,000
Automotive	300,000,000
Total	704,266,000

If these figures are correct, there is installed for each unit of our population prime-mover capacity capable of generating about seven horsepower, and at our previous estimate of 2,000,000 foot-pounds as a day's work for a man, this would be equivalent to the ability to produce for each man, woman, and child of our population if they demanded it, physical service equivalent to that which could be rendered by nearly 150 slaves.

That is what we could have if we had to with the power-producing machinery already at our service; but it is not running all the time or at full load when it does run. Mills run only forty-odd hours a week; the load factor of most central stations is less than 40 per cent. The average generating capacity of automobiles has been taken at 20 horsepower, but they utilize that amount of power only at brief intervals even when running, and are parked or in the garage the greater part of the time. Few factories, public buildings, hotels, etc. can tell anywhere nearly how many horsepower-hours they use per year.

It is impossible, therefore, to tell how hard our mechanical slaves are working or how many horsepower-hours of actual service are actually produced by them per year. Only in the case of the public utilities that make power as a commodity, the establishments that buy it by the meter, and the comparatively few of the industrial concerns that keep any intelligent record of the amount of power that they produce, can reliable statistics be had. It is evident, however, that assuming a very low use factor for the four hundred and odd million horsepower of installed prime movers, the 55,000,000 potential water horsepower of the United States would be vastly inadequate for our present demands even for the 50 per cent of the time that it would be available.

The returns show that the electric public utilities alone will produce this year 80,000,000,000 horsepower-hours. Data available indicate that the rate of electrical production by central stations is increasing at the rate of about 10 per cent yearly. If this rate of increase continues that long, they will have doubled their production in a little over seven years.

We are, then, mainly dependent for our power, and shall be unless and until some other source is discovered, upon our fuel supply.

Conversion of Energy of Fuel into Power

Fuel is capable of producing heat by reason of the attraction between its atoms, mainly those of carbon and hydrogen and those of oxygen.

A candle burns and apparently disappears; but for every pound of paraffin so burned there are discharged into the room 1.32 pounds or 35 cubic feet of water vapor and 3.13 pounds or 27 cubic feet of carbonic acid gas or carbon dioxide.

A substance is hotter because its molecules move more briskly. As the atoms approach each other under the influence of their mutual attraction, their velocity increases as does the velocity of a body falling toward the earth or the velocity of a planet as it approaches the sun. It is not the clash of these atoms that produces the elevation of temperature, but the velocity and momentum acquired as they fall together and take up their positions, whirling about one another like minute planetary systems, forming the molecules of the resulting substance, the temperature of which depends upon their mass and average velocity; that is to say, upon their average momentum.

In a boiler furnace we have the molecules of the incandescent fuel and the gaseous products of its combustion and the heated furnace walls vibrating at a rate corresponding to something between two and three thousand degrees fahrenheit. The steel walls of the boiler are composed of molecules, too, vibrating and circulating among one another in regular orbits separated by distances vast as compared with their own diameters. And yet so strong is the attraction between these widely separated molecules that it takes a force of thirty tons to separate as many of them as are exposed when a square inch of section is torn apart.

To these molecules of the steel the momentum of the furnace molecules is communicated and by them passed along to those of the water inside.

When that water was ice, the positions and orbits of its molecules were fixed. Their mutual attraction far exceeded the centrifugal force due to their rotation. But when their velocity had reached that corresponding to 32 degrees, their centrifugal force became so nearly that of their mutual attraction that they could only feebly resist displacement.

In this condition the mass can no longer hold its shape, but takes that of the containing vessel. One can push the molecules aside without effort, as when dipping his finger into the bowl, but some cohesion persists and draws the water into the drop that remains suspended upon the finger when it is withdrawn or into the crystal globe of the dewdrop. As the temperature of the water, that is, the velocity of its molecules, is raised in the boiler, their centrifugal force increases until a point is reached when they overcome the combined effect of their attraction for one another and the pressure about them and fly off, like a stone from a sling-shot, into space, producing by their bombardment upon the containing surfaces the effect that we know as pressure.

How many of these molecules do you suppose there are in a cubic foot of steam at 250 pounds pressure? Write down 82,126 and then add 20 ciphers to it and you will have the number pretty nearly.

Such numbers convey no impression. Suppose that each of the molecules in that cubic foot of 250-pound steam was magnified until its diameter was 1/200th of an inch, about as large as the dot that one would make with the point of a well-sharpened pencil; how much space do you think they would occupy? Do you suppose they would fill this room? They would fill a cube the side of which was as long as it is from here to Yonkers, or they would cover the whole surface of the earth—land and sea—to a depth of over an inch.

A pellet of lead going 100 times as fast as the bullet from a rifle or revolver would have to weigh only 1/10,000th as much to have the same energy and hit as hard, because the energy varies as the square of the velocity. If the bullet weighs 200 grains the pellet would have to weigh only 0.02 of a grain, and would require, if spherical and of lead, to be only 0.05 of an inch in diameter. The molecules of steam are small in mass but, as we have seen, great in number, and their velocity is measured in miles instead of in feet per second. There are enough of them in that cubic foot of steam, and they are traveling fast enough and hitting hard enough and often enough to maintain upon each square inch of their container a pressure of 250 pounds.

The carbon and hydrogen of the fuel have been converted into carbon dioxide or carbonic acid, the gas that makes soda water and champagne bubble, and into water vapor. A power station burning 100 tons of carbon per hour is pouring enough carbonic acid gas into the atmosphere in that time to cover a plot 100 feet square with a column 630 odd feet in height. Every fire that is burning, every animal that is breathing, is pouring out carbon dioxide, and yet there is no measurable increase in the CO_2 content of the atmosphere.

The boundless ocean and all the water that is seeking to return to it are the result of the combustion of hydrogen.

All that we need to do to get hydrogen or carbon is to decompose the water or the carbon dioxide; but it takes as much energy to pull those atoms of hydrogen or carbon away from those of oxygen with which they are combined as they generated when they fell

together, just as it takes as much energy to raise a weight against the attraction that exists between it and the earth as the weight can generate by falling the same distance.

A cubic inch of carbon in the form of anthracite would, in burning, make enough carbon dioxide to make a bubble about 15 inches in diameter.

It would take as much energy to pull the atoms of carbon and oxygen united in the molecules of that 15-inch bubble of gas apart as it would take to lift a ton weight almost 200 feet or to run a one-horsepower engine almost 12 minutes.

To separate these elements in the laboratory, we are obliged to resort to the most powerful chemical agents and to conduct the process in vessels composed of the most refractory materials under all the violent manifestations of light and heat; but in the economy of Nature this process is constantly going on, not with the noisy demonstration of prodigious effort, but quietly, in the delicate structure of a green leaf waving in the sunlight.

In some mysterious manner in the frail and microscopic vegetable cell the energy received from the sun is made to separate these atoms against their mutual attraction—to wind up the clock that has run down. The carbon is built into the structure of the growing plant and the oxygen returned to the atmosphere.

And it has been by this process that the energy of the sunlight of forgotten ages has been absorbed, built into vegetation and stored in strata of coal and pools of oil to render possible this age of power.

The earth's surface absorbs from the sun heat energy equivalent to some 3900 foot-pounds per square foot per minute. Referred to its cross-section, this means that the earth is absorbing energy from the sun at the rate of over 162 trillion horsepower.

Most of this energy is immediately radiated back to space. A small portion of it is absorbed by vegetation, some in evaporating water and inducing air currents, some in warming surfaces by day to cool off at night, and some in other ways. But it cannot be retained as heat without a rise in the earth's temperature, and there appears to be no large-scale storage of energy going on in other forms as when the coal measures were in process of formation. The energy temporarily stored in the growing tree or grain is reconverted into heat when the combustion of the vegetation takes place, either by the slow process of decay or as fuel in the furnace or food in the animal organism, and in various forms radiated, as is that from wind and water, back into the universe.

When we shall have found the secret of the vegetable cell, there may be a possibility of accelerating and intensifying this slow process of Nature and of utilizing more directly and immediately than by our round-about process of accelerating and retarding molecules, a larger proportion of this vast stream of energy that comes to us from the sun.

In the meantime practically all the use that we are making for power purposes of our current supply or solar energy, is what we get from wind and falling water and growing vegetation. That which we get from the wind is negligible, and of our present installation of power-producing apparatus in the United States about 9,000,000 horsepower is hydraulic. For the rest, as well as for the most of our heating and industrial processes, we are drawing upon the energy stored up years ago, when the crust of the earth was in its making and the luxurious vegetation of the Carboniferous age was compacted into its forming strata in the form of coal.

How Long Present Fuel Resources Will Last at Present Rates of Consumption

The end of the known supply of anthracite is approaching. There are estimated to be, of recoverable fuel of this type in the United States, some eleven billion tons, which at our present rate of consumption will last only about 100 years. It is used mostly for domestic purposes, although the smaller sizes, formerly wasted, are now used for steam making.

Of bituminous coal and lignite there are estimated to be still in the United States some $3^1/_2$ million million tons, of which about 60 per cent would be recoverable by present methods. We have already used 12 billion tons. At our present rate of consumption the rest would last some 4000 years. But our rate of consumption has been increasing for the past 25 years at a fairly uniform rate of about 18 million tons yearly. If this rate of increase continued so long we should use up our visible supply in less than 500 years.

How long and at what rate we shall continue to increase our yearly draft upon these resources depends upon our capacity to absorb light and power now made conveniently ready to our hand, what new power-absorbing processes and inventions may be discovered and developed, improvements in our processes of mining, and upon the increasing efficiency with which we may be able to use our fuel supply.

Mr. Julian D. Sears, of the United States Geological Survey, in a paper to be presented at one of the sessions of the Meeting, says that the American petroleum industry began in 1859 and it took over 41 years to produce the first billion barrels. The seventh billion was produced in a little over a year and a half. If what now remains could be continuously extracted and consumed at the 1923 rate, it would last less than 11 years. But Dr. Sears asks us not to accept this as a prediction.

As the true coal becomes scarcer and more costly, we shall doubtless learn to use peat, of which we have large supplies, which will serve to ward off for a time that doleful finish of humanity so vividly pictured by one of my predecessors in this chair when the surviving inhabitants of this cooling planet will be engaged in exterminating one another in a fight for the few remaining heat units.

Nevertheless it is not too early to have that possible plight in mind and plan to delay it as much as possible if it cannot be averted. Two thousand years is not such a long time in the history of a race that has been on earth a million years or more, and if old Tut Ankh Amen had run his kingdom by steam instead of with slaves, and the world generally had followed the practice, we should be in that predicament now.

Power is of such vital and increasing importance that its control would give its possessor a mastery over his fellows and opportunities for tyranny and extortion possessed by no autocrat of any previous empire, visible or invisible, feudal or industrial. The people may well be concerned at any gesture in that direction. Happily, their interest in the water powers has been guarded by the Federal Water Power Act of 1920, which, maintained in its integrity and faithfully administered, will retain the title of the nation in these resources, under conditions that offer opportunity to initiative, security to capital, and freedom from extortion to the consumer. Control over the distribution and sale of power by public-utility corporations is in the hands of Public Service Commissions in most of the states. But an uninterrupted and abundant supply of power cannot be assured to the nation at reasonable rates so long as the fuel from which most of it is made is subjected to the uncontrolled manipulation of private interest and the organized will—or won't—of labor.

It is to be regretted that a resource so vital to industry, so essential to their continued existence upon the present and coming plane, should have been permitted to pass out of the control of the people and be subjected to the possibilities of manipulation for private gain. The one crumb of comfort in the report of the recent Coal Commission was its declaration that the mining and distribution of coal is charged with public interest, but there appears to be little probability of the Government, as at present constituted, taking any active steps toward their public regulation and control.

Efficiencies Attained in Conversion of Fuel Energy into Power

How nearly have we come to possible perfection in the process of converting the potential energy of this fuel into power? Mr. George A. Orrok in a paper presented recently to the Society places the consumption of Savery's engine, built around the year 1600, at 100 pounds of coal per horsepower-hour, and Newcomen's engine of 1750 at about 22. A common figure for the Watt engine of the last quarter of the eighteenth century was 10 pounds, although some of the Cornish pumping engines got down to remarkable efficiencies, several records being reported in the first half of the last century of less than 2 pounds per horsepower-hour.

Trials made at Woolwich Dockyard in 1847 and 1848 gave evaporations of eight or ten pounds, averaging about 9.5 for 8 tests.

Professor Unwin reports a boiler test at about the time of the organization of this Society, showing an efficiency of 80 per cent.

With all our increased knowledge and refinements we have been able to get this up to around 90 per cent, and this only in exceptional

cases in our best-designed and most skillfully operated plants. The average for the smaller and less expertly handled plants is below 60 per cent.

There is evidently not much opportunity for improvement in the maximum efficiency, but a great opportunity for improvement in the general efficiency. This can be effected by greater attention to the design and operation of plants that are able to make their power cheaper than they can buy it, and by abandoning those that cannot justify their continued operation in favor of power from an efficient central supply.

This step should not be taken, however, without giving full weight to the value of the exhaust or extracted steam from one's own engines or turbines for heating and manufacturing processes. It takes only about 50 more heat units to make a pound of steam at 250 pounds than at atmospheric pressure, and after it has done its work in the engine it will have over one thousand heat units left in it, the difference between which and the temperature at which it is desired to use it will be available for heating and process work.

A station developing 100,000 kilowatts at 15 pounds of steam per kilowatt-hour will discharge into the river over a billion and a half B.t.u. per hour, the equivalent of which in steam for heating or manufacturing processes it would take over 85 tons of coal to make.

In steam-operated prime movers, too, we are approaching the limit of attainment for existing conditions, turbine efficiencies exceeding 90 per cent having been claimed and performances in the 80's substantiated.

A turbine of 85 per cent efficiency would need only 6.2 pounds of steam at 350 pounds absolute, 750 degrees, per horsepower-hour, and a boiler of 85 per cent efficiency could make this with about 0.7 of a pound of 12,000-B.t.u. coal. These are possibilities but not practice. A larger proportion of the coal burned for power purposes will be used at this efficiency as more of it is used in large and skillfully designed apparatus by experts in its operation.

Our progress in the boiler art has been not so much in being able to evaporate more water per pound of coal as in being able to evaporate more water per pound of boiler and to evaporate it at higher pressures.

We have single boilers today that evaporate over 150 tons of water an hour, and one boiler is being built to carry a pressure of 1200 pounds.

Our present effort toward reduction in fuel consumption is in the direction of increased initial pressures. We have already gone about as far in initial temperature as the materials at present available will stand.

The lowest steam consumption attainable by any combination of suggested processes such as bleeding, reheating, etc. would be with 1500 pounds pressure, 750 degrees initial temperature, 29 inches vacuum, 85 per cent efficiency, about 4 pounds of steam per horsepower-hour. This steam, including the heating during isothermal expansion, requires about 1400 B.t.u. per pound, and a boiler of 85 per cent efficiency would require a little over half a pound of 12,000-B.t.u. coal to evaporate and reheat the 4 pounds of it required to produce a horsepower under these conditions.

Just as the amount of power that can be gotten out of a given quantity of water depends upon the height through which it can be made to fall, so the amount of power that can be gotten out of a given quantity of heat depends upon the range of temperature through which it can be made to drop. Just as by shooting steam through a nozzle we imbue the rapidly moving jet with kinetic energy, so in raising the temperature of a body we add to the kinetic energy of its molecules. As in the turbine we recover and convert that kinetic energy by bringing the jet as nearly as possible to rest, so in the heat engine we recover as much as possible of the kinetic energy added to the molecules by slowing them down as much as possible or, in other words, by reducing the temperature to the lowest possible limit.

This lower limit is set for the steam engine by the temperature of the condensing water, the upper limit by the temperature that the available materials will stand and the pressures that increase of temperature generates in the medium.

As the temperature of water increases, the addition of a given amount of heat produces rapidly increasing increments of pressure. At 600 degrees its pressure has become over 1500 pounds. There is a limit to what we can do with steam in this direction.

By using a substance that has a higher boiling point and less pressure at these higher temperatures, the higher level may be raised without involving the limitations of uncontrollable pressures, and Mr. W. L. R. Emmet has developed this idea in his mercury turbine, with which he expects to be able, using it in series with a steam turbine, to develop a horsepower-hour on about 7500 B.t.u. equal to about three-quarters of a pound of 12,000-B.t.u. coal used in a boiler of 85 per cent efficiency.

In the internal-combustion engine there is in the cylinder itself the high initial temperature of the burning fuel, but the heat drop is limited by our inability to expand the heated gases to a low temperature level, the exhaust leaving the cylinder of a Diesel engine at a temperature higher than the initial temperature in a steam engine. Diesel engines produce a horsepower, however, on 0.4 of a pound of fuel oil, equivalent in heat value to 0.6 of a pound of good coal.

Possible Sources of Energy Other Than Fuel

Although the efficiency of our heat engines depends upon the range of temperature through which they work, the animal organism converts the latent energy of food or fuel into work without any perceptible difference of temperature. I do not know what the thermal efficiency of a mule may be, but it is inconceivable that one could get the number of foot-pounds of work that he develops, by burning the hay and grain that he eats in the furnace of a steam boiler. Perhaps in this direction lies the development of a process that will enable us to apply usefully that large proportion of the heat derived from fuel that we are obliged by our present process to reject in the low-temperature exhaust. In the primary battery we have another instance of the conversion of the energy of fuel into electricity with no perceptible temperature range and a high degree of efficiency.

We have seen that it is fruitless to think of making fuels by decomposing the products of previous combustion unless the energy to do so can be obtained, as it is by the vegetable cell, from the sun. It may, however, prove to be possible to obtain energy by the transmutation of one substance into a substance the atoms of which possess less energy of relative position or motion. It is believed that this process still going on in the sun is the source of its apparently constant supply of heat.

Dr. F. W. Aston, in a lecture before the Engineers' Club some time ago, said that if the hydrogen in 9 cubic centimeters of water could be reduced to helium, 200,000 kilowatt-hours of energy would be released, and that some time somebody may discover how this may be done. But in doing it he may set off a train of decomposition that will cause the record of his achievement to be written on the firmament in a new star.

Recent researches in electrochemistry and molecular physics have been productive of marvelous results and are full of suggestion of future possibilities. The time is not inconceivable when the tools of our present wasteful processes of power generation will be as archaic as the turbine of Hero and the engine of Papin. For the present we must use our best endeavors along established and developing lines to make the most and best efficient use of our diminishing visible resources in the face of the rapidly growing demand.

During the heating and cooling processes in the production of steel ingots or forgings severe stresses may be set up, which may attain such value as to cause a fracture in the material. Such fractures are usually accompanied by a severe shock and a ringing noise or "clink." This sound has hitherto been the only available evidence of such an occurrence rendering the forging defective, and if the fracture should happen when no observer is present or sufficiently alert to report it, the forging may unwittingly be delivered in a very dangerous condition. With the object of minimizing this danger, Messrs. C. A. Parsons and Co., Limited, in conjunction with the Cambridge Instrument Company, Limited, have developed an instrument called the "clink detector," which when attached to a forging during heating and cooling processes, gives an autographic record of any shocks or disturbances which may have taken place.—*Engineering*, Nov. 7, 1924, p. 658.

Engineers and the American Petroleum Situation[1]

By JULIAN D. SEARS,[2] WASHINGTON, D. C.

The engineers of America can perform a vital service in the conservation and economic use of our petroleum resources, and should therefore be familiar with present and future conditions in the industry. Thus far both the output and the consumption of petroleum have increased enormously, but much anxiety is felt as to whether future production can keep pace with demand.

This paper first discusses the present situation—the hazards of the industry, its demoralization during temporary periods of overproduction, and the remedies suggested for stabilization, such as increased storage, prorating runs, price cutting, shutting in wells, curtailment of drilling, and expansion of uses. It then discusses the situation of the future—the indicated growth of demand, the amount of our reserves and the possibility of increasing the percentage of recovery from them, the need for more efficient and more equitable utilization, and the necessity for developing substitutes and additional sources of supply. Several suggestions are made as to the problems which most require the attention and help of engineers.

EFFICIENCY in the use of petroleum depends almost wholly on the design and operation of machines. It is of vital importance, therefore, that the mechanical engineers of America, who must plan, supervise, and improve the means by which the oil is used, should keep in close touch with the development, the present situation, and the probable future condition of the petroleum industry. If engineers can design more efficient and economical engines, or boilers, or heating plants, or lubricating devices, they will contribute directly to the conservation of our petroleum resources. If they can determine where oil is being used for purposes or in localities which could be as well or better served by other substances, or conversely, if they can determine what industries could more profitably use oil, they will aid in a more effective utilization of our supply. When there is overproduction they can help to find new uses; when there is underproduction they can decide which plants or industries can best use substitutes. Other problems in which the assistance of mechanical engineers is needed will be emphasized in the course of this paper.

The American petroleum industry began in 1859 with a daily production of 25 barrels from the Drake well at Titusville, Pa. In 1924 nearly 300,000 wells are producing about 2,000,000 barrels a day. This enormous growth in 65 years has not been by an even increase; on the contrary, the annual production has mounted at an ever-accelerated pace. Late in 1923 the total passed the 7-billion-barrel mark. It required 41 years and 4 months, or until December, 1900, to produce the first billion barrels; 8 years and 1 month more brought another billion barrels; but only 1 year and 7 months were required for the seventh billion to be brought to the surface.

During all this period the consumption and exports of petroleum have kept approximate pace with the production and imports. As new and extended uses were found, the rise of consumption was at times the cause of the increase in production, and at times was its effect. At first, kerosene was the most desired product; now, gasoline has become the great prize, and fuel oil is of increasing importance; lubricating oils are of course always a necessary and valuable product. The growth and relations of production, imports, and consumption are shown graphically in Fig. 1.

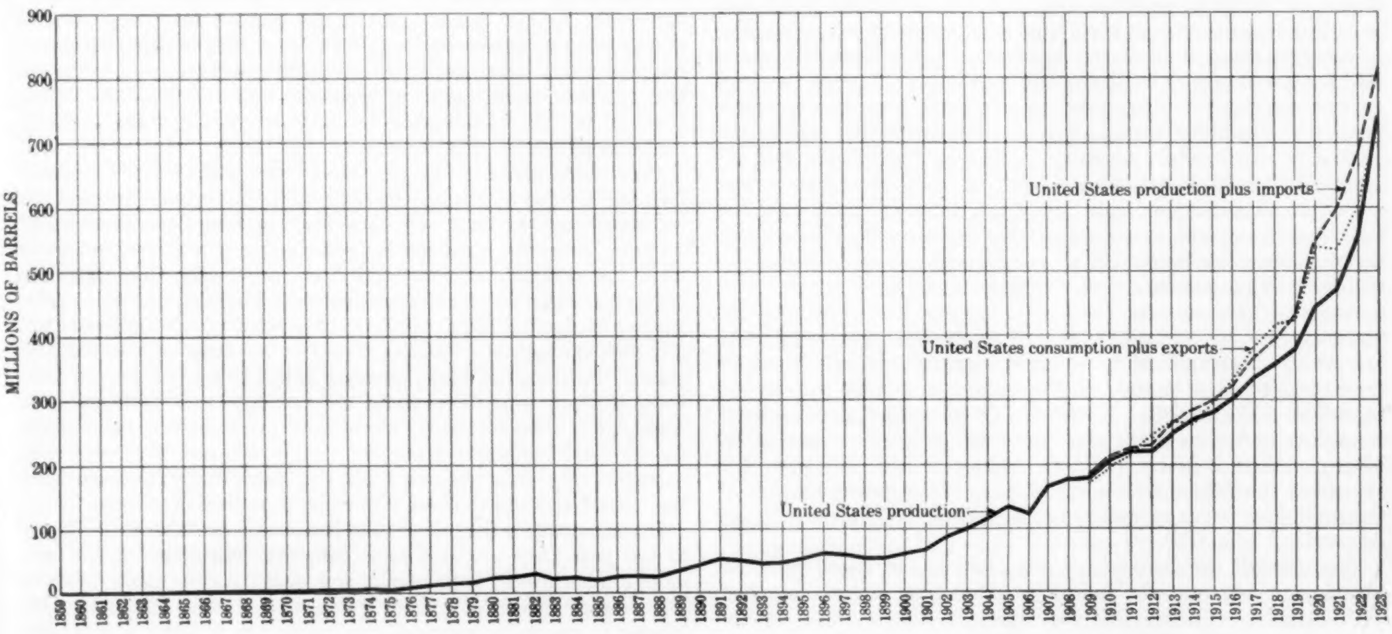

Fig. 1 Chart Showing Annual Production of Crude Petroleum in the United States, 1859–1923; also Domestic Production Plus Imports and Domestic Consumption Plus Exports, 1909–1923

The one great aim of business is profit. In weighing questions business men must constantly ask, "Can and will we make any money?" It is only natural, therefore, that to most oil operators "the petroleum situation" means primarily those conditions of present and immediate future that will influence their profit. When consumption forges ahead of production, stocks must be drawn upon, prices tend to rise, and the operators are happy. On the other hand, when production exceeds the demand, more must be exported if possible, more must be placed in expensive storage, prices tend to drop, and the oil men suffer acute misery. Such periods of gloom inspire many wails, many suggested panaceas for the oil industry—some sane, some hysterical, but all aimed at bringing the industry back to that joyous state of a ready market and good prices.

The anxiety for present profits is justifiable—for conditions that affect this great American industry affect also the prosperity of the whole nation—but present profits are not enough. Many people, among them some of our leading oil operators, have come to a broader view. They realize that the United States as a whole is deeply concerned over the distant future of our oil resources.

[1] Published by permission of the Director of the U. S. Geological Survey.
[2] Administrative Geologist, U. S. Geological Survey.

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They see that we must not only consider the temporary fluctuations of supply and demand, but must also ask whether production and consumption in the years to come will keep in balance, or whether a fast-dwindling reserve will force our production to fall far behind, in which case we may have to depend more and more on foreign supplies, and our country's commercial and domestic needs, and even our national security, may suffer.

In analyzing the petroleum situation, therefore, we should have two viewpoints. We should think first of the great industry of today as affected by more or less temporary changes, and then of the industry of the future as a long-time contributor to our comfort and security.

THE PETROLEUM SITUATION OF THE PRESENT

Hazards of the Industry

Farmers of the United States know to their sorrow that there is such a thing as crops being too good. If they raise too much corn, or wheat, or cotton, the prices of these commodities tumble, and the farmers increase their mortages on the old homesteads; on the other hand, if the demand is greater than the crops, no matter how large they may be, the farmers make money and the registration of Fords in the rural districts goes skyrocketing. So it is with the oil industry; the law of supply and demand works just the same—but there the analogy ends. If the farmers raise too much of one commodity in a year, they can plant less the following season or switch to another crop. Of course weather conditions and other hazards prevent them from raising just the proper amount to satisfy a demand estimated in advance, but at least they know that by use of proper fertilizers and by rotation of crops they can go on producing year after year, or even let their ground lie fallow for a period without harm. Not so with petroleum. Oil in the ground is an uncertain quantity; it may be "where you find it" (as the drillers say), but it has a habit of not staying there. You may have oil under your lease, but if you don't drill to it, or if you shut down your well, you will probably find later that the man on the next lease has drained it all out through his well, or that by reduction of gas pressure it may have become "dead" oil and irrecoverable. Thus in most cases each operator hustles to take out not only all of his own oil but also as much of his neighbors' as he can get by offset wells, and if the field happens to be held by many operators, its oil is brought to the surface as rapidly as possible, regardless of the market. Wasteful? Of course; but under present conditions and rules of the game the waste is largely unavoidable. Moreover there is just so much oil under any field, and when it is exhausted the field must be abandoned. That means that all of the capital invested, as well as profits, should be recovered before exhaustion.

Even though the demand for petroleum can be gaged with fair accuracy in advance, the industry cannot plan to produce just that amount. Unlike the coal operator, the oil man cannot block out underground the exact location or amount of his reserve, and then produce it on schedule. He must search for the places most likely to have oil, and then test with the drill both for actual presence and for quantity. Even with the best geologic advice his percentage of failures is lamentably large. Records show that nearly 25 per cent of all wells completed in the United States are dry holes, and it is said that in 1923 more than $91,000,000 was spent in drilling dry holes in this country. An interesting tabulation by McIntyre[1] for Kansas, Oklahoma, Texas, Arkansas, and Louisiana shows that in 1923 there were 4779 test wells drilled on leases not previously tested; in spite of the fact that many of these leases directly adjoined others that were producing, the number of dry holes was 2382, or 49.8 per cent. In these tests 111 counties gave 100 per cent failure (225 wells), and 29 other counties gave 73.7 per cent failure (614 wells). Other writers estimate that 95 per cent of all strictly wildcat tests in the United States are failures.

When we consider that wells cost from $10,000 to $100,000 or even more just to drill, that in addition to dry holes many other wells are lost before completion by tool troubles or caving, and that even if successful the wells may give only a small yield, it is not difficult to believe the figures given by Marland[1] that the American petroleum industry since its beginning has sold its raw material for $4,900,000,000 less than it cost the producing branch to drill the wells and lift the oil.

With these hazards and with such a record of loss, what is the lure that annually attracts nearly half a billion dollars of new capital into the oil business? There can be but one answer—the eternal hope of man for the "grand prize" of this lottery in which many lose and a few become wealthy.

Troubles of 1923

Some of the difficulties in the way of stabilizing the industry can best be illustrated by a review of its history for the past two years.

In the 65 years of the industry's existence only about 20 pools in the United States have ever reached a maximum daily output in excess of 100,000 barrels. Eight of these reached their peak within a period of 7 months in 1923. This unprecedented and unlooked-for flood of oil was largely the result of a great drilling campaign begun several years earlier because of rising prices and the belief in an impending shortage. By August, 1923, half of the production of the United States, or 1,000,000 barrels a day, was coming from only 3500 wells in 8 fields; the other million barrels were coming from 275,000 wells scattered through the rest of the country. Less than 2 per cent of the wells were yielding 50 per cent of the oil. The nearly simultaneous development of so many great flush fields is a coincidence that most oil men believe can never happen again. But it did happen this time—and as one oil operator plaintively said, "The year 1923 brought the greatest production of crude oil, the greatest consumption of crude oil, the greatest consumption of gasoline, and the greatest annual increase in the consumption of gasoline—and yet the industry made no money!" Let us see why this was so.

Only three times in the preceding three years—and then only for a week or so at a time—had our domestic output exceeded our consumption. In 1923, at a time when imports from Mexico had seriously dwindled, production in this country began to run away from the demand. For several years previously California had been producing less than it needed; now its great new flush fields gave an excess that began to move at the rate of 1 to 6 million barrels a month through the Panama Canal to refineries on the Atlantic coast. Oil from the Mid-Continent fields, in general moved eastward through pipe lines, could not compete with the California shipments. This fact alone would have made matters bad enough for the Mid-Continent operators, but in addition they were embarrassed by several huge flush fields of their own. They sold what they could and ran the rest into rapidly increasing storage.

In the meantime the refiners had been having trouble also. Early in the year they installed more efficient "cracking" outfits, ran more crude through their plants, and built up great stocks of gasoline in anticipation of a huge spring and summer demand. Due largely to weather conditions the increase in demand was far less than expected, and by July 1,600,000,000 gallons of gasoline were in storage—more than 53 days' supply. The Mid-Continent refiners were particularly affected, as their markets to the west, east, and north were restricted by the flood of California and Wyoming crude. For a time prices were maintained by marginal contracts, but gradually more and more gasoline was dumped on the market to liquidate stocks. New retailers, unhampered by contracts, could buy this "distress" gasoline and build up a cut-rate trade. Finally in August, at the peak of the motoring period, price slashing began in earnest, stimulated partly by the entrance of one of the western states into the retail business.

Suggested Remedies

By September the daily production reached its maximum of 2,280,000 barrels (see Fig. 2), and the industry was in a veritable panic. Meetings of different groups were held, and many suggestions were made for improvement of conditions. The cooler heads cautioned against hysteria, and pointed out that overproduction was only temporary; that it was due merely to the simultaneous development of great flush pools which would inevitably show a

[1] McIntyre, James, Hazards of Drilling for Crude Petroleum, *Oil and Gas Journal*, vol. 23 (1924), no. 16, p. 68.

[1] Wagner, Paul, Threatened Regulation of Oil Concerns Landowner Most, Says Marland, *National Petroleum News*, vol. 16 (1924), no. 18, p. 61.

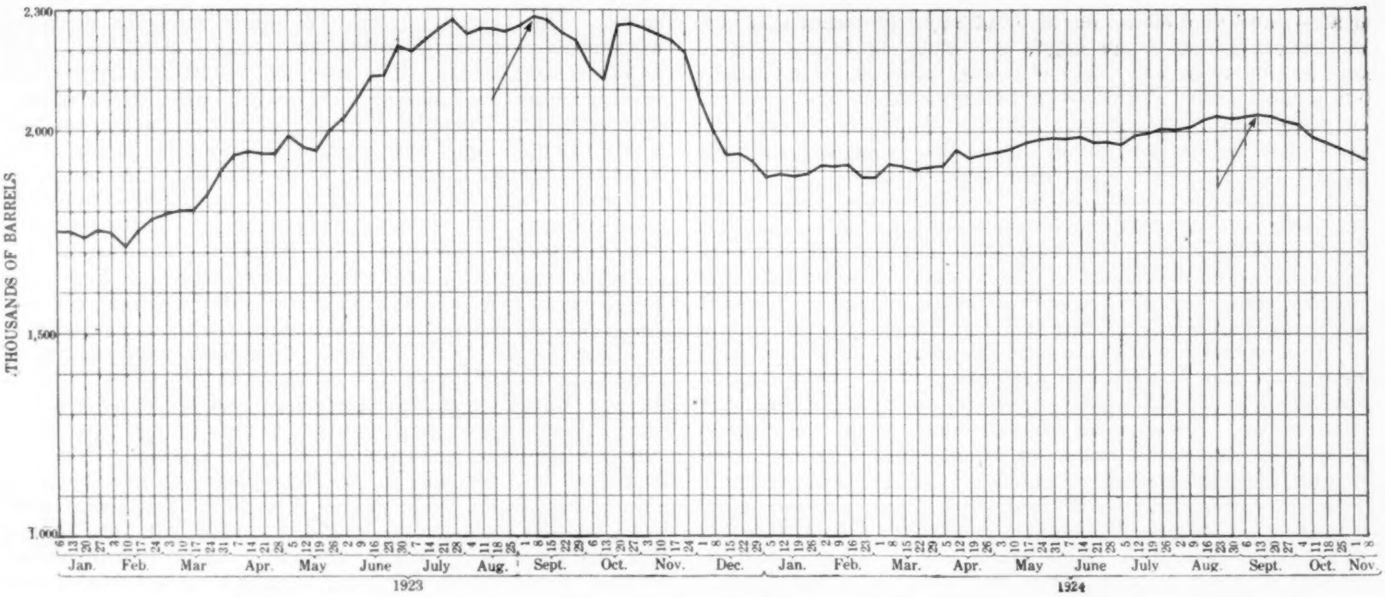

FIG. 2 CHART SHOWING AVERAGE DAILY PRODUCTION (ON A WEEKLY BASIS) OF CRUDE OIL IN THE UNITED STATES, 1923–1924
(Figures from the American Petroleum Institute.)

rapid decline; and that the ever-growing demand would soon overtake a falling output.

Lowering the price of crude was vigorously combated by producers. They claimed that only those who happened to own large flowing wells were making any profit; that those who were trying to keep small wells under pump, with relatively large lifting costs per barrel, would be forced out of business by decreased prices. The small wells with settled production, they truthfully said, are the backbone of the industry, and will be its mainstay long after the big flush wells are exhausted. Half the oil in the country was being obtained from 275,000 wells making less than an average of 4 barrels a day; 55,000 wells in Oklahoma and Kansas yielded less than 2 barrels apiece, and many of the Pennsylvania wells had a daily output of less than 1 barrel each. These, they said, would be ruined if shut in. If we could count on an indefinite number of flush pools in the future we could afford to let these small wells go, but we must protect them. Consumers would temporarily benefit by price cutting, but later would have to pay much higher prices because of the loss of the steadily yielding wells. (It may be said in passing that recent developments in California and elsewhere are showing that this supposed injury to wells by pinching or shutting down is actually a fallacy.)

Voluntary shutting in of producing wells and prorating of runs and curtailment of purchases by pipe-line companies to force decrease of output were among the suggestions; these plans were opposed by some because of the supposed injury to wells by pinching in or stopping the flow. To avoid this alleged damage, several of the purchasing companies adopted the plan of buying half the output and running the rest into storage for the operators at a small monthly rental; this plan really stimulated production, as the operators wanted to make the half that they were selling as large as possible.

Operators were urged to curtail wildcatting and also to halt the drilling of wells in progress, at least before tapping the productive sands. This very sensible suggestion was difficult to put wholly into practice, because of the divergent interests of so many operators.

Increase of storage was a much-debated plan. Its advocates reasoned that storage would stabilize the industry by preventing the dumping of oil on the market during periods of overproduction and by furnishing a reserve supply at a moderate cost during slack periods. Its opponents contended that further increase of stocks would be very dangerous. Pogue[1] said that the theory of stabilization by storage causes "an artificial demand for crude petroleum which has played a part in overstimulating supply. The practice of this theory has created wider fluctuations in price and greater instability than would otherwise have been the case. Economic experience has shown time after time that industrial prosperity always follows depleted inventories, and large stocks are to be shunned as the precursors of depression." Others pointed out that steel storage is very expensive to provide, and that the fire hazard and loss by evaporation are very great; one company with 40,000,000 barrels of crude in storage was said to have lost $1,000,000 in July by lowering of gravity through evaporation. In spite of the decrease of imports from Mexico, the stock of crude petroleum held by pipe lines and tank farms was growing at the rate of a quarter of a million barrels a day, an increase from about 253,000-000 barrels on January 1, to about 314,000,000 barrels on October 1, or 24 per cent; this amounted to about 150 days' supply. Other large stocks of crude, refined, and partly refined oil were held by producers and by refiners. This huge stock, it was stated, was an unfair burden on the industry by the tie-up of funds. These arguments were contested by others who claimed that stocks were not excessive; that although the actual amount held was the largest in history, yet the ratio of the petroleum stored to the annual consumption was considerably less than the average over a period of 15 years. These defenders of large stocks pointed out also that improved methods for preventing evaporation were constantly being adopted and that waste in storage would thus be less in future.

H. L. Doherty urged efforts to furnish a market for surplus products by greatly stimulating new uses, especially the adoption of oil burners for domestic heating. He offered figures to show that only 7 per cent of our coal output need be displaced to give a market for 200,000,000 more barrels of oil annually. Shortly after Mr. Doherty's speech, campaigns to increase the use of domestic oil burners were under way in Toledo, Kansas City, and several other communities. Such widening of the scope of oil consumption, building up a great demand and hence raising prices, may work a temporary benefit to the industry, but from the national viewpoint it is a somewhat questionable policy. More will be said on this subject.

LATER DEVELOPMENTS

As might have been expected, there was little uniform or concerted action on these suggested remedies. Storage stocks continued to increase; some wells in California and the Mid-Continent fields were shut in; prorating of pipe-line runs began, and finally substantial cuts in the price of crude oil were announced. Daily output, which had begun to fall off, was forced upward again by the mounting flush production of the Long Beach (California) and Powell (Texas) fields. However, in the middle of November the skies suddenly brightened, prorating in the Mid-Continent was lifted, and a purchasing campaign began, because, as one writer expressed it, "High-grade Oklahoma crude is such a bargain

[1] Pogue, J. E., What's Wrong with Oil?—*Oil and Gas Journal*, vol. 22 (1923), no. 10, p. 122.

at $1 a barrel that almost any habitual buyer recognizes that fact, and cannot forbear to buy largely of it while the buying is good and as long as he has a foot of storage room in his supposedly full tanks." After Thanksgiving (which no doubt was a real one for many of the Mid-Continent operators) the big flush pools began their predicted decline, and by the middle of January the daily output had decreased more than 300,000 barrels. This lower rate of production continued for several months, prices slowly rose once more, and by spring the operators began to feel that they were out of the woods. The flush fields, they said, had now come down to a settled production; the number of automobiles was steadily rising, and the demand for crude oil and its products was mounting rapidly. Some bolder spirits again began to talk of an oil shortage within the next few months, as no new large flush fields were in sight; one went so far as to predict that by September production would be 500,000 barrels a day less than consumption. However, by June the daily output had climbed to 1,984,000 barrels, and again the cry was heard, "Too much production, too much storage—prorating is looming—curtail drilling!" Prices were dropping, and "distress" gasoline and crude were again appearing. California oil was still moving to the Atlantic seaboard at the rate of more than 100,000 barrels a day. Automobile registrations, although larger than ever before, had not increased as fast as expected, and the sale of gasoline had again been retarded by a disagreeable spring. Efforts were made to secure shutdowns in several of the menacing Mid-Continent fields, but these attempts as well as later price cutting and prorating seemed to have little effect. By August the daily production had increased to 2,005,000 barrels, and by September it had reached 2,030,700 barrels, only 250,000 barrels less than the maximum just a year earlier

In this rather lengthy summary the author has tried to show some of the difficulties and hazards of the oil industry as illustrated by its recent hectic career, and to point out some of the methods by which stabilization is attempted. Basically, he believes, the industry is sound; but because of its speculative nature it must at times secure large profits to carry it over the lean periods. As one operator has said, "The leading states of the American petroleum industry may be California and Oklahoma—but its chronic states are hope and despair." Truly the oil business is one which, for success, requires courage and hope, shrewdness, a keen analysis of the ever-changing conditions—and a reasonable share of good luck.

The Immediate Outlook

The situation at the present writing (September, 1924) and the outlook for the rest of 1924 may be summarized as follows:

Stocks on hand July 31, 1924, were reported by the Geological Survey and the Bureau of Mines to be:

Crude oil, domestic and imported, in pipe-line stocks and tank farms, 356,240,000 barrels (176 days' supply), an increase in stock of 19 per cent over that of a year before.

Crude oil, domestic and imported, at refineries, 39,970,000 barrels, an increase of 19 per cent over the stock of a year before.

Gasoline, 1,466,544,000 gallons.

The demand for crude oil in 1924 will probably amount to about 803,000,000 barrels. This figure is indicated in two ways. The actual demand for crude in the first 6 months of 1924 was 9.7 per cent greater than for the corresponding period in 1923; if this rate holds for all of 1924 the year's needs will be 802,676,000 barrels. Again, the demand for the first half of 1923 was 47.1 per cent of that for the entire year; if the demand for the first six months of 1924 bears a similar ratio to that of the entire year, the total domestic consumption plus exports for 1924 will be 803,554,000 barrels. It is true that if the demand in 1924 was as much greater than the demand in 1923 as the latter was in comparison to that of 1922 (21.4 per cent), it would be about 887,000,000 barrels. Also, simple extrapolation of the crude of "U. S. consumption plus exports" in Fig. 1 would indicate a demand in 1924 of about 850,000,000 barrels. However, these higher figures, while interesting to consider as possibilities, cannot justifiably be used as a safe basis for planning.

Estimates of supply are much less certain. There is little indication of change in imports, which will probably be nearly 90,000,000 barrels. Last year the domestic production reached 732,407,000 barrels. This year the output will almost surely be smaller; it will probably not exceed 720,000,000 barrels, and may fall as low as 710,000,000 barrels. It is true that 413,159,000 barrels were produced in the first 7 months of 1924 (nearly 5,000,000 barrels more than in the first 7 months of 1923), and that production has been slowly rising for some time; nevertheless, using the figures of the American Petroleum Institute, the average daily production for the week ending August 30, 1924, was only 2,030,700 barrels, compared with 2,261,800 barrels one year before. In the same week only two pools—Long Beach and Smackover—reached a daily output in excess of 100,000 barrels. There seems to be little likelihood that any new bonanza fields of the Santa Fe Springs or Powell type will be developed this year, though the unexpected may always be looked for in the oil business. California's production is remaining somewhat higher than anticipated; this is due partly to the new Torrance and Dominguez fields and to the reopening of some wells in the older pools, but even more to the fact that the decline of Long Beach is much slower than was expected. Nine new fields have been developed in Oklahoma thus far in 1924, including a deeper sand in the Tonkawa pool; of these the Tonkawa, Stroud, and Cromwell pools are the largest producers, but there is hope that their rising output will be curbed by operators who are warned by their lesson of 1923. Texas, Louisiana, and Arkansas may show a slightly increased yield by the growth of some of the smaller fields like Luling and Cotton Valley or by the development of several new pools. Wildcatting in Kansas and Colorado is very active, but the new high-gravity oil fields in northwestern Colorado and northwestern New Mexico are still in the early stages of development, and because of their relative inaccessibility will have no effect in 1924, even though they ultimately prove to be far larger producers than now seems likely. Wyoming and Montana are expected to show little change.

If we accept as reasonable the figures given above, it seems probable that in 1924 the domestic production plus imports will be about 810,000,000 barrels, and will slightly exceed the domestic consumption plus exports. In that case stocks will be drawn upon only to a limited extent in the second half of the year, and by January, 1925, should still be somewhat larger than at the beginning of 1924.

If there proves to be any great variation from this estimate the author believes it will come in increased production by the unexpected rise of one or more pools. There seems to be small chance that the year's output will be much less than the lower figure given, as the decline of the big flush pools of 1923 has now come to a slower rate and their yield has been added to settled production.

THE PETROLEUM SITUATION OF THE FUTURE

So much for the condition of the industry today. Let us turn to the problem which is of far greater concern to the country as a whole—the petroleum situation of the years to come.

Growth of Demand

The growth of demand and its comparison to supply from 1909 to 1923, inclusive, are shown diagrammatically in Fig. 1, and also in Table 1.

TABLE 1 DOMESTIC PRODUCTION, DOMESTIC PRODUCTION PLUS IMPORTS, DOMESTIC CONSUMPTION PLUS EXPORTS, AND RATE OF INCREASE OF DEMAND, 1909–1923

Year	Domestic production, bbl.	Domestic production plus imports, bbl.	Domestic consumption plus exports, bbl.	Rate of increase of demand, per cent
1909	183,171,000	183,237,000	171,141,000	....
1910	209,557,000	210,128,000	195,785,000	14.4
1911	220,449,000	221,910,000	215,707,000	10.2
1912	222,935,000	229,844,000	244,207,000	13.2
1913	248,446,000	265,424,000	265,492,000	8.7
1914	265,763,000	282,676,000	263,929,000	−0.6
1915	281,104,000	299,243,000	294,539,000	11.6
1916	300,767,000	321,564,000	328,515,000	11.5
1917	335,316,000	365,443,000	382,415,000	16.4
1918	355,928,000	393,664,000	417,174,000	9.1
1919	378,367,000	431,188,000	426,481,000	2.2
1920	442,929,000	549,104,000	539,289,000	26.4
1921	472,183,000	597,547,000	534,972,000	−0.8
1922	557,531,000	684,839,000	602,595,000	12.7
1923	732,407,000	814,422,000	731,701,000	21.4

In only two years during this period has there failed to be a substantial increase in the demand. Even more important is the fact that in all but two years since 1911 the domestic consumption plus

the small exports of crude petroleum exceeded the domestic production by 13 to 96 million barrels. Imports, chiefly from Mexico, have covered the deficit and helped to build up our storage supply.

There is every reason to believe that demand in future will continue to increase at an equal or greater rate. Consumption by present means is constantly growing and new uses will undoubtedly be found, particularly if the price of oil remains about the same as today.

Automobiles are by far the greatest consumers of gasoline. The phenomenal rise in the number of automobiles in this country, shown graphically in Fig. 3, would have caused an acute shortage in the supply of fuel had not improved refining methods greatly increased the yield of gasoline from each barrel of crude. Future growth of automobile registration may be confidently expected; the "saturation point" predicted so freely some years ago has long since been passed, and now a total of 30,000,000 cars is suggested as possible. At present more than 40,000 motor buses are in operation on city and interurban routes; the use of these and of trucks for freight hauling will expand materially.

The commercial use of airplanes is still in its infancy, and will almost surely increase greatly as safety and carrying capacity of

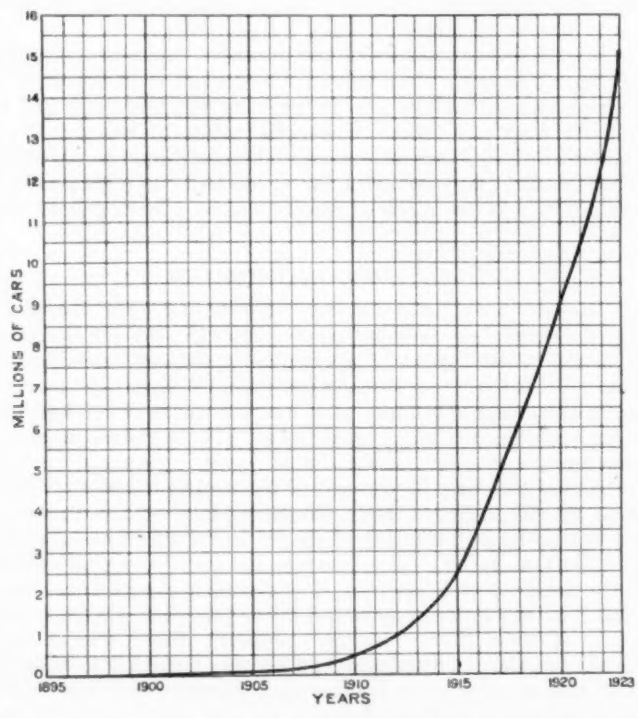

FIG. 3 CHART SHOWING ANNUAL REGISTRATION OF AUTOMOBILES IN THE UNITED STATES, 1895–1923
(According to the National Automobile Chamber of Commerce.)

the planes are improved. Motorcycles, submarines, tractors, and farm electric-light and power plants can also be counted upon to enlarge considerably the demand for gasoline and light distillates.

The oil-burning steam engine and the Diesel engine are being rapidly adopted for merchant shipping. In 1914 there were 501 oil-burning vessels in the world, with a gross tonnage of 1,721,747. By 1920 the number had increased to 2021 vessels with a gross tonnage of 9,039,247; three years later there were 3348 vessels of 16,478,104 gross tons which were burning oil. The Shipping Board is planning to convert a number of its vessels to the Diesel type, as a step to lower costs and greater efficiency in competition; the United Fruit Company has ordered 3 new banana-passenger vessels, each to be equipped with Diesel-electric-drive engines of 3000 shaft horsepower; according to Lloyd's Register there were under construction at the close of last March 139 motorships of 689,433 tons, of which nearly half were being built in Great Britain and Ireland. Other shipping lines are realizing the advantages of oil over coal and will follow the example.

In 1923 the railroads of the United States consumed 45,000,000 barrels of fuel oil, just a little less than was used by our merchant vessels; electric plants consumed nearly as much; gas manufacturers about 22,000,000 barrels of gas oil, and other industries about 125,000,000 barrels of fuel oil. Increased use in all these lines will undoubtedly be a large factor in swelling the future demand for petroleum.

Last, but far from least in national importance, is the consumption of about 6,000,000 barrels of fuel oil annually by our Navy. Quickness and ease of fueling and the increase of speed and cruising radius with oil-burning engines make oil for this purpose a vital necessity. Consumption by the Navy may not grow as fast as that in the various industries, but an assured supply is of prime importance.

There can be no reasonable doubt that as a whole the country's need for petroleum will continue to mount steadily in the future as it has in the past. Possibly in a century, or in a few years, some new and radically different form of energy may supplant gasoline or fuel oil, but this is too problematical to be considered.

FUTURE PRODUCTION—OUR RESERVES

What, then, of our future production—can it increase year by year to keep pace with demand, or will it rise for a time and then, because of dwindling reserves, begin to fall farther and farther behind?

We have already seen that about half the output in 1923 came from small, settled wells; this yield cannot at present be appreciably increased. Production in the declining flush pools may be raised by reopening shut-in wells or by further or deeper drilling. In a large way, however, the output from wells can be increased only by improved percentage of recovery, which is an ideal to be attempted, or by the addition of new flush fields, which is dependent upon how fast the new pools can be located and developed, and even more upon the number of such pools now remaining undiscovered. Geologic knowledge and faster drilling are constantly speeding up the finding and development of new fields, but if no great number of pools remain to be found, the lean years are close at hand. This question has been and still is a storm center of controversy.

Not long ago the president of one of our largest oil companies stated: "We have faith in the industry that....it will locate new fields of supply as rapidly as expanding consumption on the one hand or the failure of existing sources of supply on the other provide markets for the new production." This optimistic attitude is shared by a number of operators and writers, who heap ridicule upon those who predict a coming shortage. They point out that estimates of our total reserves have repeatedly been revised upward because of the discovery of fields not previously known and therefore not taken into account; they say that new fields have always been found and production has always been increased as fast as necessary, and that therefore such conditions will continue in the future. This is very unsound reasoning. Whether the number of undiscovered pools or of barrels in the ground is large or small, the fact remains that the number is actually limited, and that it is growing ever smaller. Each pool found leaves one less to be found; each barrel of oil taken from the ground leaves one less to be recovered. Greater production does *not* prove greater reserves, but faster exhaustion; it does *not* show that the hogshead is larger, but merely that the bunghole is larger. Where can be found these new pools that the optimists so glibly predict? For a time they may come from the newer oil states whose production curves are still on the upward grade and which have not yet been thoroughly tested, but sooner or later these states must inevitably follow the example of those older areas like Pennsylvania, West Virginia, Ohio, Indiana, and Illinois, whose curves have long since passed their peak and are now on a steady decline.

Of course estimates may have to be revised as new facts appear; if estimates contained final figures they would cease to be estimates. But as one writer[1] has aptly said: "The geologists may have been fooled once and they may be fooled again, but they are not fools. They have the weight of evidence on their side and it's going to stay there. We are using up our underground capital. We are not subsisting on the interest therefrom. It is going to be exhausted. The only thing which we do not know is when that exhaustion is going to take place."

In 1922 the United States Geological Survey and the American

[1] Cary, Harold, Motor Fuels and Engines of the Future, *Oil and Gas Journal*, vol. 22 (1923), no. 25, p. 36 (reprinted from *Motor*).

Association of Petroleum Geologists jointly estimated that our reserve supply *recoverable by present methods* was about 9 billion barrels. If what now remains of this supply *could be continuously extracted and consumed at the 1923 rate* of 700,000,000 barrels annually, it would last less than 11 years. Please notice that this is not a prediction, for we know it could not happen; it is merely a supposition to illustrate the size of our reserves. Unfortunately, in the past similar suppositions by the Director and other members of the Geological Survey have been received with howls of derision by certain men who carelessly or maliciously ignored the qualifying clause. There is little or no excuse for such misinterpretation, especially in view of the following explanation in the joint estimate of 1922: "The committee expressly decries the too frequent assumption that inasmuch as the estimated reserves appear to be sufficient to meet the needs of the country at the present rate of consumption for 20 years, therefore the reserves will be exhausted at the end of that time or, at most, a few years later. This assumption is absolutely misleading, for the oil pools will not all be found within that length of time, drilling will be spread over many years, as the pools are found, and the wells cannot be pumped dry so quickly. Individual wells will yield oil for more than a quarter of a century, and some of the wells will not have been drilled in 1950. In short, the oil cannot all be discovered, much less taken from the earth, in 20 years." The actual result of approaching exhaustion will be declining production and increasing dependence on other sources of petroleum. And what, in principle, does it matter if the geologists' estimate of our total reserve proves to be 50 per cent too low; or if (as the author cannot believe possible) the reserve is ten times as large as supposed? The vital fact remains—our supply is not inexhaustible, and when once extracted it is gone forever. Even forests, now causing so much concern because of their dwindling extent, can be replanted, but oil once used cannot be replaced.

Is the author unduly pessimistic—an alarmist? He believes not. Though sober thought warns us against prodigal waste of our store of oil, yet the future is by no means hopeless. *Please bear in mind that predictions of shortage are based partly upon the inefficiency of present methods of production and use.* We must consider means by which total output can be increased and consumption be made equitable and efficient.

Greater Recovery

Present methods of extracting oil give pitifully poor results. It is estimated that when the average field is "exhausted" and ready to be abandoned, at least 80 per cent of the original oil content is left in the ground. Generally this is because the gas pressure has become so reduced that it cannot force the oil out of the pores of the rocks. It is essential, therefore, to conserve gas pressure in active fields and try to make each cubic foot of gas help in bringing as much oil to the surface as possible. Petroleum engineers of the Bureau of Mines and the Standard Oil Company of California and others believe that this is best accomplished by rapid drilling and comparatively close spacing of wells. Attempts to renew exhausted pressure by compressed gas or air, by water flooding, and by natural gas under its own pressure have been quite successful in several older fields. The problem of greater recovery is worth the serious consideration of engineers; it is bound to receive intense study in future, as obviously our production can be enormously increased if a larger fraction of the underground supply is made available.

Greater Efficiency in Handling and Consumption

Waste of the first output from gusher wells can be prevented by better control valves and adequate provision for temporary storage. Safeguards for permanent storage have been greatly improved in the past few years; the loss by evaporation and fire is now greatly reduced by water sprays, water sealing, insulation, floating roofs, and similar methods. The Navy has succeeded so far as to provide storage for fuel oil which, it is claimed, will have an evaporation loss of only 1 per cent in 10 years. E. L. Doheny says he is building water-sealed and insulated tanks in which gasoline may be stored for years; rising vapors can be piped to an absorption plant where the gasoline will be extracted and returned to the tanks. Further progress along these lines should ultimately provide means for storing fuel oil and gasoline for an indefinite time without appreciable loss.

As the demand for gasoline has risen, new methods have been adopted for increasing the percentage of gasoline from each barrel of crude. If this is carried too far, and too much gasoline is extracted, the supply of fuel oil and other products may be greatly below the demand—a process of robbing Peter to pay Paul. The country would be far better served by expansion of the casing-head or natural-gas gasoline output, and still more by greater efficiency of future motors; simple mathematics shows that if mileage can be doubled by improved carburetors, by lighter cars and smaller engines, by the use of mixed fuels, and by better highways, twice as many automobiles as are now in use could be operated with the present output of gasoline. The high price of motor fuel in Europe has forced the adoption of more economical engines; should not the automotive engineers of America effect similar improvements before they are forced to do so by public demand? Even the proper adjustment of present carburetors by all motorists would be of marked assistance; it is claimed that an average increase of only 10 per cent in mileage would mean a saving of more than half a billion gallons of gasoline a year, the equivalent of more than 100,000 barrels of crude oil a day, or the output of 50,000 of our established wells. Surely this is worth saving!

Higher efficiency of Diesel and other engines is of course a problem equally worthy of intensive study by engineers.

Efforts made here and there to reclaim the oil drained from crank-cases have met with some success; the material is being used in burners and as a road oil, also for greasing concrete forms and as a dip for hogs and cattle. For conservation of our petroleum resources all these efforts are commendable and should be extended; as the Director of the Geological Survey has said: "A million gallons reclaimed is a better mark of service than a million gallons discovered."

New Sources of Petroleum

As already noted, our domestic consumption plus the small exports of crude oil have for some years exceeded the domestic production, which had to be augmented by imports, chiefly from Mexico. If in future our demand continues to exceed the domestic output, the deficit may force us to ever-increasing dependence on foreign supplies, and the United States will be placed in active competition with other nations for the world's oil resources. It is estimated that only 18 per cent of the world's reserves are controlled by this country. Even though we may be able to secure an adequate supply, the cost of oil per barrel would certainly be far higher than today. The American industry has already taken steps to acquire foreign reserves; their control is of such importance to our country's future welfare and safety that some governmental support of these efforts may be justifiable. Some writers even urge that foreign companies should not be permitted to take oil out of this country while holding their reserves elsewhere intact against our future decline. It seems probable, however, that in the future other countries will draw more heavily upon foreign reserves, and that lessening exports of our refined products will leave a greater proportion of our supply available for domestic consumption. In striking contrast to this appeal to guard our oil from the inroads of other nations is the plea of one writer for tariff protection against a threatened flood of cheap Mexican oil; this seems to be a very shortsighted suggestion to give the oil industry temporary profits at the expense of our resources.

Even better than foreign supplies would be new sources of petroleum in this country. Mr. Doheny suggests that some production may be obtained in future from the oil sands saturated with solid or semi-solid bituminous residue, such as those in several California districts where the oil is thought to have turned to bitumen or asphalt when gas escaped from the upturned edges of the strata.

A more obvious and probably far more valuable source is the oil shale of our western states. Oil shale has three great advantages over natural petroleum: its supply is relatively unlimited, it can be kept in the ground cheaply and indefinitely without loss or deterioration, and it could be mined at a rate comparable to the demand. However, it is not yet in commercial competition with well oil for two reasons. First, unlike natural petroleum, which needs only to be tapped by the drill and then pumped or allowed to flow to the tank, oil shale must be mined on a scale comparable

to that of soft-coal mining; even where steam shovels might be used this is a vast undertaking, as about a ton of shale will be required for each barrel of oil produced, and the disposal of the huge amount of worked-over material is a serious problem. Shale oil, unlike petroleum, cannot be labor-cheap. Second, methods for extracting petroleum from the shale by distillation are still largely in the experimental stage, but certainly under the stimulus of a waning supply of well oil and consequent rising prices such processes will be perfected. All signs indicate that this stimulus is only a few years away, but we should not wait for it. The author believes that we should encourage active and intensive efforts to put extraction processes on a profitable basis, and that the Government, through the Bureau of Mines, can render great public service by undertaking such investigations on a large scale. By the approval of the President and the Bureau of the Budget, Congress has been asked to appropriate $90,000 for this purpose; it is hoped that the measure will be cordially supported by engineers and others who are convinced of its merits. If the shale-oil industry is once established on a firm basis it should remove anxiety as to supplies for many years to come, especially a supply for national defense.

Substitutes for Gasoline

Further attention should be paid to the possible development of other motor fuels to augment the supply of gasoline. Because of their individual characteristics some of the fuels may be much more valuable for blending than for straight use; for example, benzol alone will freeze in winter weather, but mixed with gasoline it is supposed to facilitate starting, to add power, and to increase mileage. Alcohol may prove of great value for blending, though considerable modification of engines would be needed to permit its use alone. F. W. Ormandy, the English physical chemist, has studied the production possibilities of alcohol, and claims that if any one of several varieties of vegetation were planted in South Africa on an area equal to the County of Kent, it would produce enough alcohol to supply Great Britain with motor fuel. Other supplies may be gotten by the distillation of lignite and the hydrogenation of coal.

Equitable Division of Supply

From time to time analyses have been made of the relative value of petroleum products as compared to coal and other fuels. Comparison must be based not only on the amount of heat derived from equal volumes or weights of the fuels, but also on the availability, the ease of handling, and other factors. Uses of petroleum fuels may be divided into three classes: those in which oil is practically indispensable or extremely desirable, such as illuminating gas plants and marine engines, particularly for the Navy; those in which oil is desirable but not indispensable, such as many processes like glass making; and those in which oil can be used to advantage but in which other fuels can serve equally well, such as steam boilers and heating plants. Even within any one group of consumers there are varying degrees of necessity; for example, certain railroads can more advantageously burn oil because of their remoteness from good supplies of coal, whereas other railroads find coal or electricity of greater utility.

In view of the possible future shortage of oil and the range in necessity for its use, it is a fair question whether we should continue to let the law of supply and demand take its course—that is, to let the various users decide for themselves what fuel is most practicable under existing conditions—or whether by a campaign of public education or by Government control there should be an apportionment of supply to consumers on a basis of their respective needs. Certainly the national defense is of prime importance and must be insured, but is there warrant for radical change in the present order? To the author the whole matter hinges upon the forecast for future production. If the output for many years to come is dependent upon well oil with a percentage of recovery no greater than today, we are almost certainly facing a serious shortage that should discourage the replacing of coal by oil for steam-raising and heating plants. If on the other hand we can be sure of increased recovery from wells and of great commercial yields of shale oil, we may well rest content to let consumers decide which fuel is more profitable. Personally the author feels optimistic that the genius of American engineers, if turned toward these problems of increasing our supply, will be successful. But no matter what the outcome, in either case greater efficiency in the use of our supply should be always held as a goal. Conservation has been defined as "not hoarding, but the wise use of natural resources," and it behooves us all as good American citizens to aid wholeheartedly in making the truest economic use of our national heritage of petroleum.

Modern Oil-Cracking Methods[1]

Processes Commercially Employed in Cracking Crude Oils to Obtain Gasoline—Data on Yields and Costs of Installation of Units—Comparative Results when Operating on 35–36 deg. B. Mid-Continent Gas Oil

By H. L. DEBAR, TULSA, OKLA.

THE fact that petroleum oils could be cracked by the aid of heat and pressure was discovered some time previous to any extensive commercial application of the idea. Though preceded by many experiments, Dewar and Redwood developed their process in 1890, which is very similar in principle to the successful processes now operating.

No further advance seems to have been made in the industry until about 1914, when the Standard Oil Company of Indiana began installing the Burton process in their various large refineries, at the same time endeavoring to limit the use of other processes by claiming a basic patent on the cracking of oil. This situation remained unchanged until about 1918, when the Cosden Company, after a careful investigation of the patent situation, decided to install a large number of units of the Coast process. In 1922 a considerable number of processes reached a stage of development where the patentees were ready to place them on the market, and at about this time the Standard Oil Company of Indiana offered to license the Burton process on a basis similar to that of the independent processes. It is therefore seen that successful cracking methods have been open to the independent refiner for but little more than a year.

The list of installations given in Table 1 shows the widespread use of cracking processes at this early date. It is impossible to state exactly how much gasoline is produced by cracking methods at the present time, but it is safe to state that with the completion of all

TABLE 1 INSTALLATIONS OF UNITS FOR CRACKING PETROLEUM OILS

Process	Number of Refineries	Number of Units
Burton	?	?
Coast	3	125
Fleming	15	?
Cross	18	81
Dubbs	20	31
Muehl	1	4
Jenkins	2	4
Holmes-Manly	3	?
Isom	?	?
Bruin	6	?
MacAfee	1	?

[1] Additional information regarding certain of these processes will be found in a paper by C. M. Johnson entitled, The Manufacture of Gasoline by the Cracking of Heavier Oils, published in MECHANICAL ENGINEERING, December, 1924, pp. 879–885.

Presented at a joint meeting of the Mid-Continent Sections of The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, Tulsa, Okla., April 28, 1923. Abridged.

of the above units, at least 125,000 bbl. will be produced daily. This is equivalent to about 625 carloads, or 13 trainloads, daily.

Descriptions of Various Oil-Cracking Processes

Burton Process. The Burton process was developed in 1915 and 1916 by Dr. Burton and E. M. Clark for the Standard Oil Company of Indiana. It employs an 8-ft. by 40-ft. cylindrical still mounted above the furnace in the manner usual to refinery practice. The vapor line passes to an aerial condenser and then to a condenser capable of withstanding the still working pressure. A vapor drum is placed in the control house to receive the condensate, after which the pressure benzine passes through a meter and a relief valve to storage.

A charge of approximately 250 bbl. is pumped into the still at the beginning of the run. The pressure is then built up to 80 lb. per sq. in. at once by the injection of gas into the still. This process has been operated on both the batch and semi-continuous principles; when operating as a batch still the initial is the only charge, and the cycle is of approximately 48 hours. When operated in a semi-continuous manner an additional charge of approximately 110 bbl. is introduced during operation, and the cycle lengthened to 60 hours.

The operating pressure of this process is 90–95 lb. per sq. in. The oil during processing reaches a temperature of 780–800 deg. fahr., and a yield of approximately 28 per cent of New Navy gasoline is obtained from Mid-Continent gas oil.

In order to prevent the deposition of carbon on the heating surface, "Humphrey" pans are installed. These pans are placed above the regular bottom and promote a rapid circulation of oil below, with a decreased tendency to deposit the free carbon until in the space of slower movement above the pans.

The cost of this process is from $35,000 to $40,000 per unit, or $250 per bbl. of daily capacity.

Coast Process. This process was developed in 1918 by J. W. Coast, Jr., while with the Cosden Company. Like the Burton, it consists of a shell still and operates under approximately the same pressure, but the pressure is released before the vapors reach the condenser instead of after condensation as in the Burton process. The carbon is removed from the heating surface by a scraper consisting of knives bearing on the heating surface.

A yield of 28 per cent New Navy gasoline is produced from the usual Mid-Continent gas oil. The cost of a unit of this process is approximately $30,000, or $187 per bbl. of daily capacity.

Fleming Process. This process was developed in 1920 by Richard Fleming at the Shell refinery, Martinez, Cal. Though of the shell type, it has several unique features. Contrary to the usual custom the still is placed on end, the reason being that the heating surface is increased by heating the entire circumference of the still and also that the carbon has less tendency to deposit on the perpendicular surfaces. Since the bottom of the still is not heated, no harm can result from an accumulation of a considerable amount of carbon.

Probably the most novel feature of the process is the jet condenser, which occupies little more space than an ordinary 3-in. gate valve and in which the still pressure of about 110 lb. is maintained up to the jet.

TABLE 2 COMPARATIVE RESULTS FROM VARIOUS PROCESSES OPERATING ON 35–36 DEG. B. MID-CONTINENT GAS OIL

	Process					
	Burton	Coast	Fleming	Cross	Dubbs	Holmes-Manly
Type of heater	Shell	Shell	Shell	Tubular	Tubular	Tubular
Vaporizing chamber	Shell	Shell	Shell	None	Shell	Shell
Still pressure, lb	90	80–90	110	650	165	250
Condenser pressure, lb	90	...	...	None	165	250
Type of condenser	Pressure Coil	Atmospheric Coil	Jet	None	Pressure Coil	Pressure Coil
Temp. of oil, deg. fahr	780	750	800	870	860	...
Initial charge, bbl	250	250	310	21	80	...
Feed in, bbl	100	150	250	3900	5275	...
Total charge, bbl	350	400	560	3921	5355	...
Total cycle, hours	60	60	72	144	240	...
Average daily capacity, bbl	140	160	187	653	535	600
Cost of unit	$35,000	$30,000	30,000	$40,000	$60,000	...
Cost per barrel	$250	$187	$160	$61[1]	$112	...
Percentage of New Navy gasoline	28.0	28.0	36.1	33.3	40.3	40
Barrels per day	39.2	40.8	67.5	218	216	...
Cost per barrel	$893	735	$445	$183	$278	...
Percentage of intermediates	...	...	43.3	53.3	23.0	...
Percentage of fuel oil	...	...	12.6	9.4	31.1	...
Per cent loss	...	6.0	7.5	4.0	5.6	...
Royalty per bbl. charged	$0.16	$0.12	$0.15	$0.10	$0.15	...
Fuel used, percentage of charge	12	11	8	...	..	...
Amount of oil in heater, bbl	250	250	310	...	10	...

[1] This includes only the manufacture of synthetic crude, no distillation.

On Mid-Continent gas oil an average of 36 per cent New Navy gasoline is obtained. The cost of a unit is approximately $30,000, which is equivalent to $160 per bbl. of daily capacity.

Cross Process. This process was developed by the Cross Brothers of the Kansas City Testing Laboratories and the first commercially successful installation was made at the Indian Refining Company, Lawrenceville, Ill. In the most recent design the gas oil, or what is now termed "synthetic crude," passes into a still, in which it is vaporized at atmospheric temperature by its own latent heat. The rising vapors from this still pass to the heat exchanger, where they warm the incoming gas oil. The vapors are then liquefied in a condenser and are ready to be further refined.

The normal cycle time of this process is six days, which is practically continuous, and the charging capacity is 650 bbl. per day. Average runs on Mid-Continent gas oil have shown yields of $33^1/_3$ per cent New Navy gasoline. A unit of the above capacity costs approximately $40,000, or $61 per bbl. of daily output.

Dubbs Process. The Dubbs process was developed by Jesse A. Dubbs, beginning in 1915, and the first commercial installation was made at the Roxana Petroleum Corporation refinery at Wood River, Ill. Like the Cross process, it has a tubular heater, through which the gas oil passes before entering the expansion chamber. Vaporization takes place and the carbon is deposited in the expansion drum.

The cost is approximately $60,000 per unit, or $112 per bbl. of daily capacity. On the average 40 per cent New Navy gasoline has been produced from Mid-Continent gas oil. On account of its large storage space for free carbon, this process is capable of cracking fuel oil practically as well as gas oil.

Muehl Process. A process has been developed by W. Muehl of the Interstate Refiners, Inc., that has shown excellent results from a small installation of three stills. The process is being enlarged at the present time, and, with the improvements which have been recently made it is practically a continuous system of a very economical design. Placing the estimated output at a very conservative amount, the construction cost per barrel of capacity will probably be the lowest for any process.

The oil is first heated in this process in two vertical tubular heaters somewhat resembling a Wickes boiler. The hot oil flows from the heaters to two horizontal cylindrical "digesters" where the cracking action takes place. The carbon is deposited in these digesters and expelled from the system by scrapers which force the carbon into the tar pots from which it is drawn off continuously.

Since the heating surface in this process is three times as large as in any other process and the "digesters" or expansion chambers are six times as large, it is believed that a considerable quantity of oil can be treated daily. The heaters are cleaned alternately, allowing the process to run continuously with a cycle at least a month long.

Jenkins Process. The first installation of the Jenkins process was made at the American Gasoline Plant Corporation refinery in Kansas City, Mo., in 1921. The process comprises a tubular heater connecting two drums located at the lower end of vertical legs extending from each end of a horizontal shell still. A motor-driven impeller is operated in the rear leg to produce a rapid circulation through the tubes in order to prevent the deposition of carbon therein.

A production of 35 per cent New Navy gasoline from Mid-Continent gas oil has been obtained. The cost of a unit, complete, is approximately $100,000, or $217 per bbl. of daily capacity.

Other Processes. There are a number of other processes now in more or less successful use which cannot be described at this time but which should be mentioned in order to show the thought that is now being given to the subject of oil cracking. These are the Isom (Sinclair Refining Co.), Holmes-Manly (Texas Company), Ellis (Standard Oil Co. of N. J.), MacAfee (Gulf Refining Co.), Hoover, Greenstreet, Bruin, and the Emerson impact processes.

Comparative results from the various processes that have been described, operating on 35–36 deg. B. Mid-Continent gas oil, are given in Table 2.

The Turbine Designer's Wind Tunnel

By H. LORING WIRT,[1] SCHENECTADY, N. Y.

This paper describes air-testing methods developed by the General Electric Co. for testing elements of turbines by simulating the conditions in the turbine with models and determining their relative performance, and from these results predicting the effect of similar changes on the turbine. The streamline and eddy flow through the passageway tested is clearly indicated by flow casts that show both the flow lines and the shape that caused them. The issuing stream of air is explored with impact tubes, static tubes, and angle-measuring devices. A combined traversing, plotting, and enlarging mechanism makes it possible to take a series of accurate impact traverses covering the whole of the jet. These traverses are mechanically evaluated and from them the efficiency of the nozzle is found by a method of graphical triple integration.

The paper includes curves from tests of two types of nozzles showing how improvement has been made and illustrating the value of the method in designing turbine elements. Illustrations of casts of buckets and right-angle bends further emphasize the value and generality of the method.

THIS paper describes briefly methods developed by the General Electric Company to accelerate advancement in the art of turbine design and to insure correct design of all the elements of a turbine that control and guide the flow of steam from the control valve through the nozzles, buckets, and exhaust hood to the condenser. The rapid improvement of the airplane is based on an infinite amount of painstaking wind-tunnel research, and in much the same way improvements in the turbine have been pointed out by the "turbine air test," which in reality is the turbine designer's wind tunnel.

The air test was started over four years ago on top of a two-inch pipe, and has grown so that there are now two test stands supplied through 6-in. pipes with air at 90 lb. per sq. in. pressure. The air test is run continuously—that is, days, nights, and overtime. Over

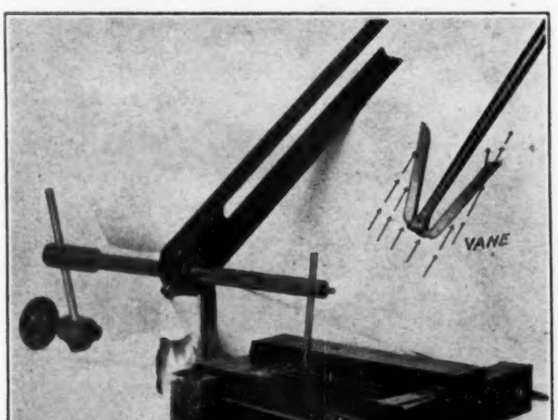

Fig. 1 Double-Vane Angleometer with Telescope and Protractor

eleven hundred different models have been tested, ranging in variety from those representing turbine problems to elements of turbo-air compressors and ventilation of electrical machinery. Air-test methods similar to those developed could be adapted to ventilating and aerodynamical problems, in fact they are universally applicable to any problem that concerns the flow of a fluid, be it compressible or incompressible. The methods can be used to design streamline valve passageways for water, air, or steam or to indicate the flow around the nose of a projectile, airplane, propeller, or ship model.

The streamline and eddy flow through the passageway is clearly and beautifully indicated by flow casts that show both the flow lines and the shape that caused them. Also the issuing stream of air is explored with impact tubes, static tubes, and angle-measuring devices. In particular a combined traversing, plotting, and enlarging mechanism has been devised that makes it possible to take quickly a series of accurate impact traverses covering the whole of the jet. These traverses are mechanically evaluated with curve-drawing templets, and from them the efficiency of the nozzle is found by a method of graphical triple integration. The final value of efficiency of a nozzle is the result of approximately nine hundred readings of impact pressure. Exhaust hoods, interstage passageways, valves and the like are tested by measuring the volume flow through them for any initial pressure ahead of them and plotting pressure-flow curves.

Description of Air-Test Method

For example: It is desired to find the relative efficiency of two

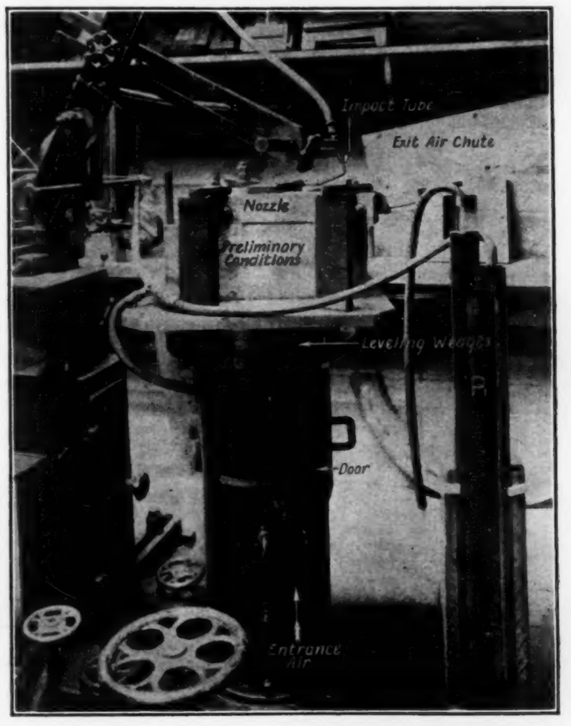

Fig. 2 Test Table Showing Part of Traversing Machine

proposed types of construction. A model nozzle will be made of each as shown on Fig. 1. The sides and ends are made of mahogany and the two plates of steel are let into the sides about $^3/_{16}$ in. Three passageways only are constructed. The discharge from the first and third passageways serves to support properly the center jet. The sides and ends of the model are held together with dowels and through bolts in order that it may be taken apart readily. Model nozzles for the center stages of a turbine are made full size. Those for the first stages are enlarged two or three times, while last-stage nozzles are generally made one-half to one-third full size.

Test results are worthless unless the nozzle being tested is fed by air in the same way that the corresponding nozzle in the turbine is fed by steam. Proper feeding requires that the nozzle be preceded with a suitable guiding passageway (called the "preliminary conditions"—see Fig. 2) that simulates the discharge from the previous bucket. The radial height of the "preliminary conditions" is made equal to the length of the active discharge portion of the preceding buckets.

The angles of discharge from the "preliminary conditions" into the nozzle entrance at the big and small diameters are equal to the absolute angles of discharge from the tip and root of the bucket Angle measurements are made of the steam discharge after wheels of

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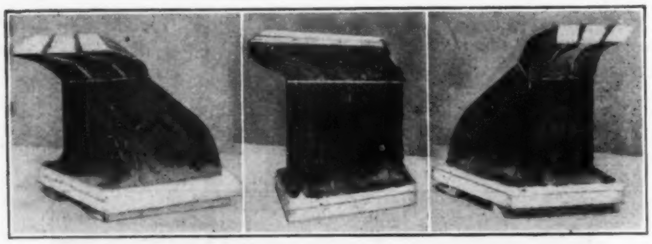
turbines in operation indicate that the measured angle of discharge is practically equal to the angle obtained from a velocity diagram, and consequently the latter angles are used to determine the angle for the preliminary conditions.

Fig. 3 shows a cast of the interior of such a nozzle and "preliminary conditions." It will be seen that at the left side the approach to the nozzle is at 45 deg., while at the right side it is straight, due to the different absolute angle of discharge from the tip and root of the preceding bucket. This picture also shows clearly the two plates of the nozzle, as well as the general shape of the nozzle in the radial-flow direction.

Fig. 4 shows that a model nozzle fed in this way truly simulates turbine conditions. Figs. 4-*A* and 4-*B* are views of the discharge surfaces of diaphragm plates that have been in operation for two or three years, and show the markings caused by boiler compound and other impurities in the steam. Fig. 4-*C* shows similar markings obtained on the air-test model by placing dots of liquid paint on the nozzle surfaces and blowing at the proper velocity. In about a minute the paint took the form shown and the flow was stopped instantly with a clapper valve. The comparison proves several things: First, that the markings on the actual diaphragms are not due to water in the last stages of the turbine but are due to eddy flow of the steam itself, since in the air-test model there was no water. Second, the air-test markings duplicate remarkably well the turbine markings. At the side of the big diameter there is the same eddy in both cases, and there is also a throat line parallel to the exit edge of each plate. The close similarity of flow indicates that the model nozzle is being fed in the correct way, and that therefore turbine conditions are being duplicated. Consequently gains shown by the air test should be realized in the turbine.



A B C

Fig. 3 Cast of Typical "Preliminary Conditions" for Testing Last-Stage Nozzles

(*A*—Left-side view, 45-deg., approach; *B*—Back-view, discharge into paper and up; *C*—Right-side view, straight approach.)

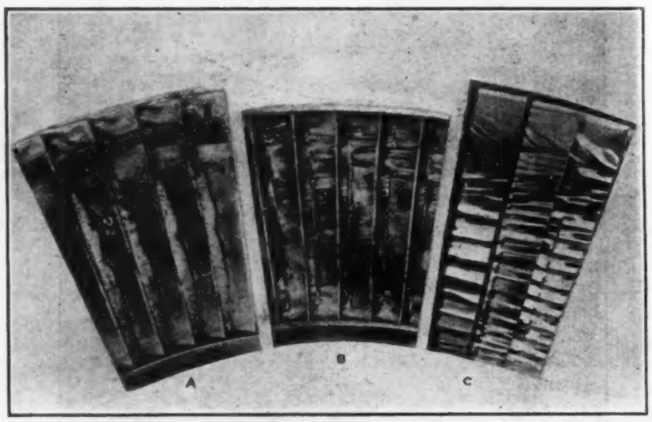


Fig. 4 Flow Lines on Exit Side of Nozzles Proving that Turbine Flow Conditions Are Duplicated in Air-Test Models

(*A*—Turbine diaphragm; *B*—Turbine diaphragm; *C*—Air-test model.)

The nozzle and its "preliminary conditions" are bolted down on the top of the test stand shown in Fig. 2. The air is controlled by the valves at the bottom so that the pressure is constant in the front of the nozzle at a value that will give a nozzle velocity corresponding to that in the turbine.

The initial pressure is measured by an impact tube projecting into the center line of the "preliminary conditions" and pointing in the direction of the approaching air. Thus it reads the total initial energy by adding the effect of velocity of approach to the static pressure. The discharge from the nozzle escapes upward to the right (see Fig. 2) through the exit air chute.

The center jet is explored in testing, overlapping somewhat into the first and third jets, by means of an impact tube held in the traversing mechanism shown in Fig. 5. This device is a combined traversing, plotting, and enlarging machine improvised from a scrapped grinding machine. The three feeds are used to move the impact tube in three rectilinear directions. The location along the path of the traverse of the point of the tube is known at all times by the position of the edge of the ruler on a flat table or by the edge of the tool rest which rubs on the revolving drum. By means of a steel wire and ratio wheel this drum can be made to revolve at any enlarged ratio up to twenty times full size. The impact tube is connected to both a simple U-tube and differential U-tube that are immediately in front of the operator. These tubes are selected so as to have uniform bore in order that it may be sufficient to read one side of the U-tube only and plot this value to the proper double scale.

In using the traversing machine the operator with his right hand moves the impact tube in small increments and with his left plots the value of impact pressure on the revolving drum. The points when connected give a curve like any one of the heavy curves on Fig. 6 or 7. It is clear that as the point of the impact tube moves along on a circumferential traverse from a region of high velocity in the center line of the first nozzle to a point in line with the partition exit edge, it will move into a region of lower velocity due to the loss caused by the plate and the eddies following it. This will produce a dip in the impact curve, the two dips corresponding to the two plate edges. Fig. 6 shows most of the traverses of the set for the first type of nozzle. The traverses are spaced further apart in the center of the nozzle where there is little difference from one traverse to another, while at the sides where the difference between traverses is great the spacing is reduced to $^1/_8$ in. or less.

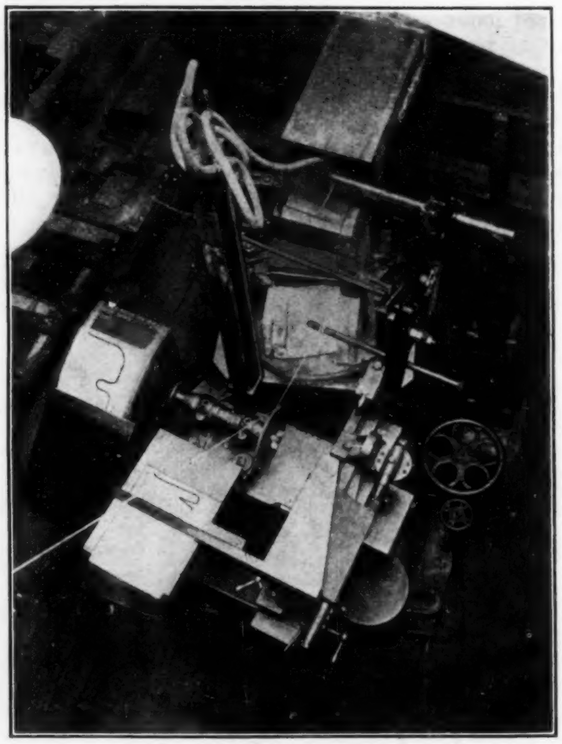


Fig. 5 Top View of Combined Traversing, Plotting and Enlarging Machine Improvised from a Scrapped Grinder

Fig. 7 shows a set of traverses on the second type of nozzle. The better performance is self-evident since the dips are small and the impact pressure comes up to maximum between them. Before describing how to evaluate impact traverses it will be well to discuss paint casts and how they are made.

The best way that has been found to indicate streamline flow

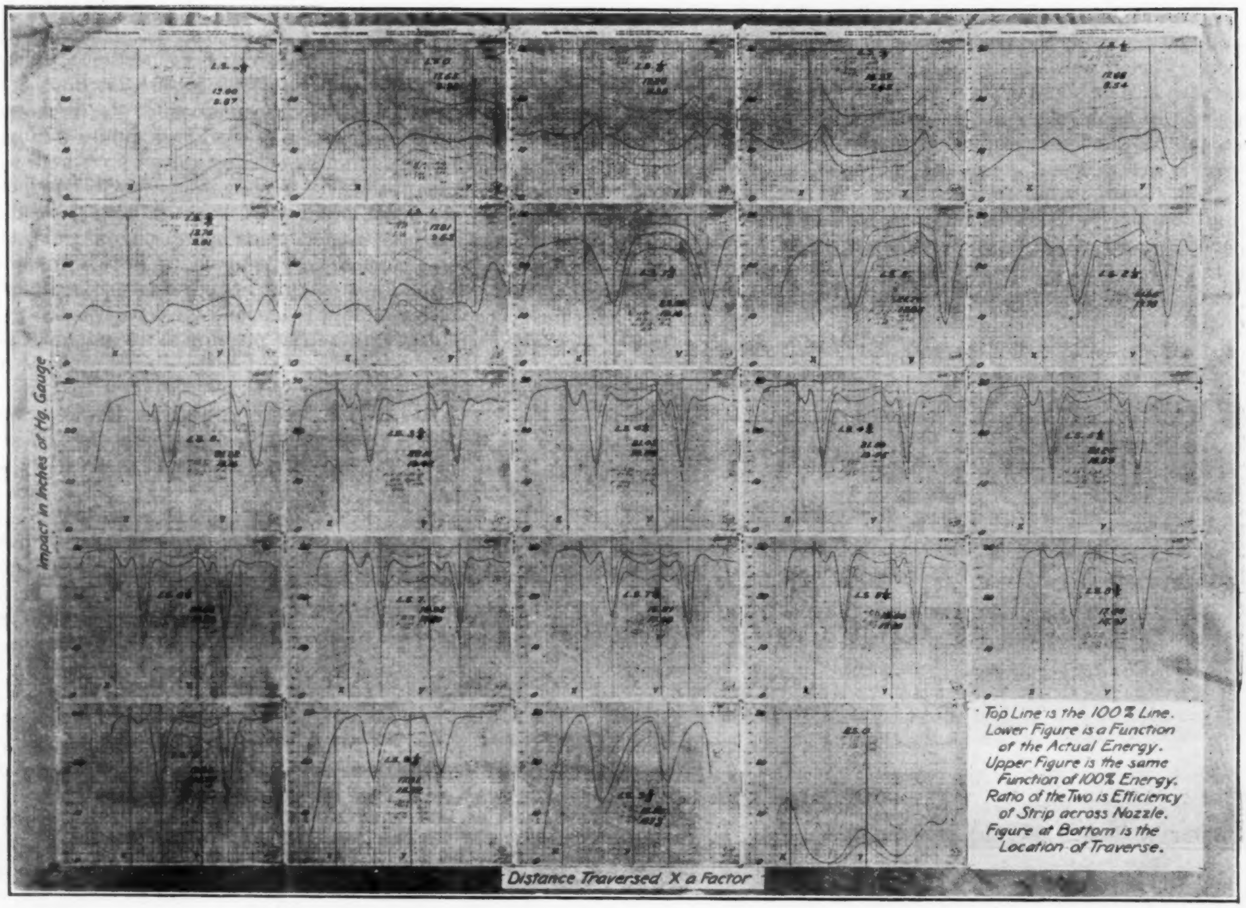


Fig. 6 Set of Impact Traverses on an Inefficient Type of Nozzle

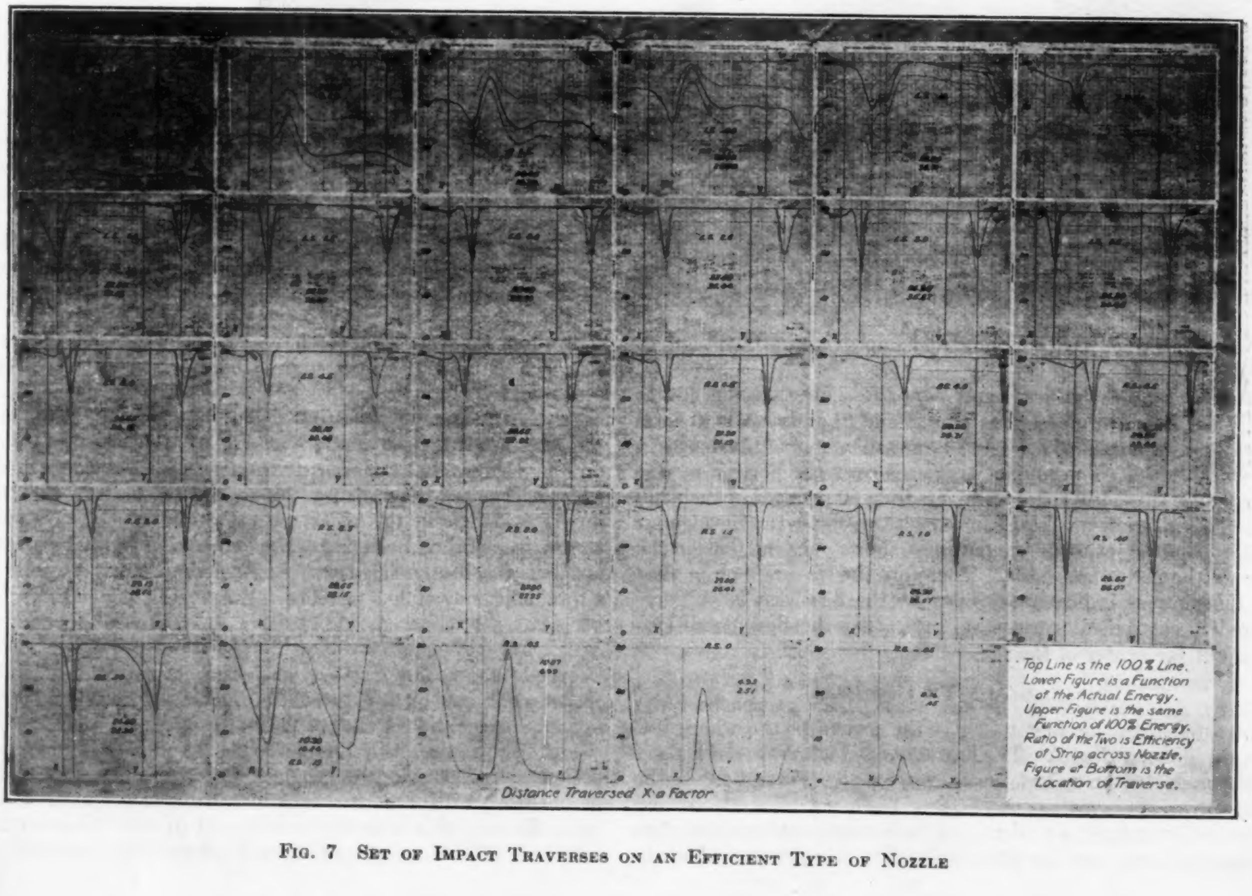


Fig. 7 Set of Impact Traverses on an Efficient Type of Nozzle

through a model is to paint the interior surfaces with a mixture of lampblack and neatsfoot oil. The model is then clamped on to the test stand and blown at the proper velocity, generally about 1200 ft. per sec. The air blows away most of the paint and streaks the remainder out into fine lines in the direction of flow with clear places in between. In about a minute, when the desired consistency of lines is obtained, the flow is stopped instantly with a clapper valve. The model is removed and the interior filled with plaster of paris, which, when it hardens, absorbs the lines. By taking the model apart the cast can be removed and lacquered, thereby obtaining a permanent record of the streamline flow through the model as well as the shape that produced that flow. Ever since turbines were first designed, streamline flow and eddies have been discussed; accordingly this method is of immense value in showing what and where the eddies actually are, thereby eliminating guessing and much loose talking, and enabling real improvement in design to be made.

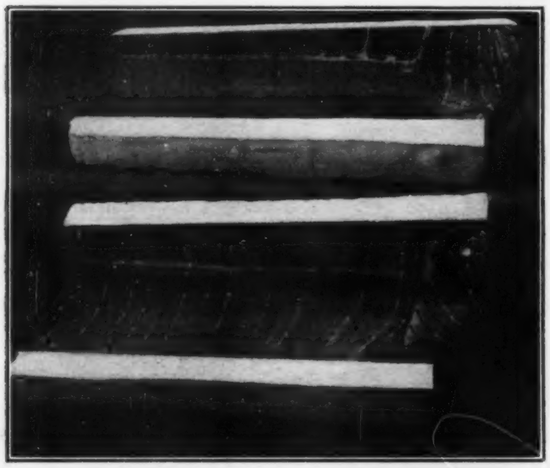


Fig. 8 Flow Casts of Inefficient Nozzles

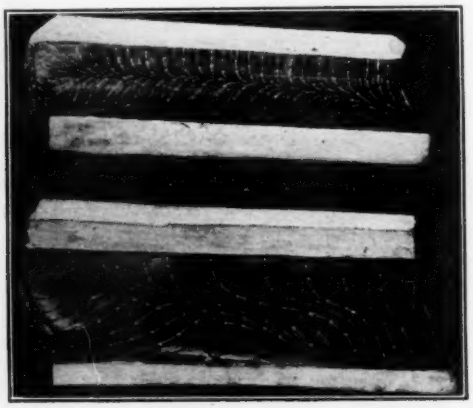


Fig. 9 Flow Casts of Inefficient Nozzles

Fig. 10 Flow Cast of Efficient Nozzle

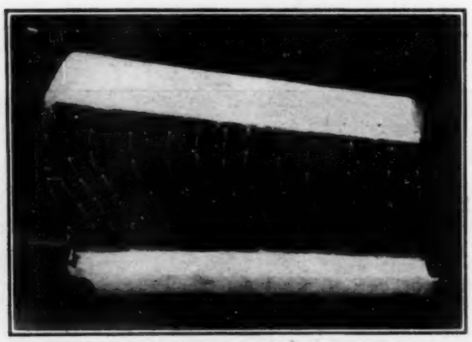


Fig. 11 Flow Cast of Efficient Nozzle

The flow casts of the first type of nozzle show that the flow is actually backward in places (see Figs. 8 and 9) and that in general the side of the nozzle toward the larger diameter is filled with a large spiral eddy. The impact traverses over the portion of discharge fed by this eddy come up to less than 50 per cent of their full value. This is significant, since an impact traverse is run throughout the interior of the jet while the flow cast shows only the flow on the surface of the plates and walls. Therefore the traverses prove that when this flow as indicated by lines on the flow cast is properly analyzed it can be interpreted as indicating the flow conditions throughout the center of the jet.

Comparison of Two Nozzles

Contrasted with this first nozzle is the second nozzle whose traverses are shown in Fig. 7. The flow casts in Figs. 10 and 11 show that the good traverses are due to perfect streamline flow in the nozzle.

From the foregoing it is evident that the second nozzle is a considerable improvement over the first nozzle, but the question to be answered is: How much is this improvement in per cent? The answer is obtained by applying a method of graphical triple integration to the impact traverses. Briefly, the initial temperature and pressure are known and the final static pressure is atmospheric. If the impact pressure equals the initial pressure, or, in other words, comes up to maximum, the usual equations for the discharge of an elastic fluid from an orifice can be used to compute the mass and energy discharged per unit area. If the impact pressure is less than maximum, a similar solution for mass and energy is possible if it is assumed that all of the initial energy that fails to show up as observed energy has been used to reheat the discharging air at atmospheric pressure. Therefore, in a region of low impact pressure there will be less mass and less energy per unit area per second for two reasons: The velocity of flow is less, and the density is less.

Celluloid templets with impact pressure as an argument are used to draw in curves of mass and energy that are roughly parallel to the curve of impact pressure. Those curves can be seen faintly in Figs. 6 and 7. The area of the mass curve when multiplied by scale factors gives the total mass discharged per unit width. If this mass of air had expanded from its original pressure and temperature to the final atmospheric pressure with an efficiency of 100 per cent, it would have set free an amount of energy that is called the "100 per cent energy." Consequently, the mass is multiplied by the 100 per cent energy per unit mass to obtain the 100 per cent energy. The area of the energy curve when multiplied by scale factors is the actual energy. Then the ratio of the two, the actual energy divided by the 100 per cent energy, is the efficiency of the traverse.

The efficiency of the nozzle is found by plotting the values of actual energy and 100 per cent energy found from each traverse as ordinates and the traverse spacing as abscissas, thereby making a loss diagram as shown on Fig. 12. The area under the lower curve is the actual energy and the area under the top curve is the 100 per cent energy, and the ratio of the two is the efficiency of the nozzle. The area between the two curves, therefore, is the loss. A comparison of the loss diagram on Fig. 12 with the lower flow cast on Fig. 8 shows that the excessive loss near the left side is due to the eddy. The loss diagram for the second nozzle (see Fig. 13) has no excessive loss at this place and the cast also shows no eddy. A comparison of the efficiencies of the two nozzles showed that the first nozzle had a total efficiency of 82.9 per cent and the second nozzle a total efficiency of 96.6 per cent, a gain of 13.7 per cent.

Other Typical Tests

Fig. 14 shows flow casts of long buckets and indicates the disturbed character of flow through a bucket. The flow is backward in many places and the ends of the bucket are filled with large eddies.

Fig. 1 shows the set-up for measuring the angle of discharge. The design of the double-vane angleometer is the result of much experimenting with various shapes of vane, and the vane shown has been the only type that has been found to work properly at high velocity. Flat vanes shaped like a flag split a high-velocity jet and

read the angle of one current of flow or the other current of flow. A double-vane angleometer has its active edge inclined to the impinging jet so that each increment of edge has an undisturbed stream striking it. Sufficient torque is developed along the line of the active edge to turn the vane and so indicate the angle. The angle is read by means of a telescope with cross-hairs.

Valves, right-angle turns, exhaust hoods, and the like are tested by measuring the flow through them for any pressure ahead of them and comparing their flow curves with the flow curve of an orifice of equal area. Fig. 15 shows flow casts of three types of right-angle turns. The square corner is slightly better than the round corner, while the addition of blades reduces the loss in the turn to one-sixth of its previous value. The improvement in streamline flow caused by the blades explains this tremendous reduction in loss.

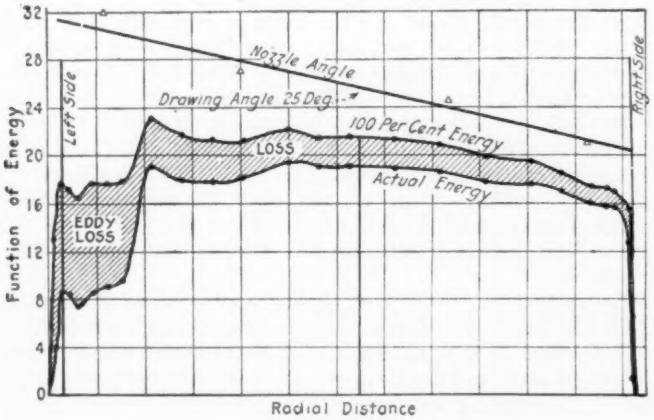


FIG. 12 LOSS DIAGRAM OF INEFFICIENT NOZZLE
(Total efficiency, 82.9 per cent.)

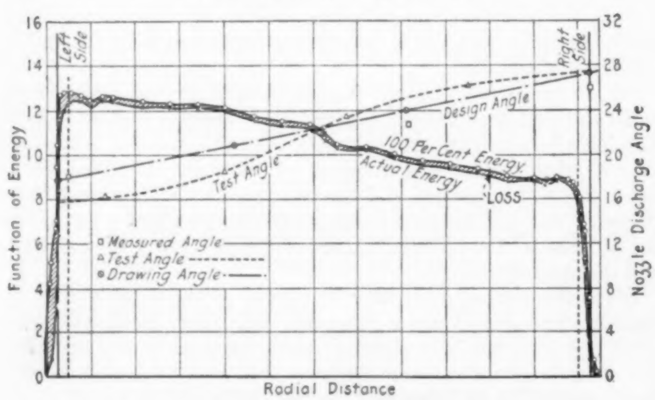


FIG. 13 LOSS DIAGRAM OF EFFICIENT NOZZLE
(Total efficiency, 96.6 per cent; gain 13.7 per cent.)

ADVANTAGES OF THE AIR-TEST METHOD

From the foregoing it will be seen that these methods of investigation have many advantages which previous methods have lacked: namely,

a The performance of each part of the nozzle is observed in detail and so cause and effect can be isolated in a way that is impossible in any nozzle-testing machine which gives only the final result and from the nature of its operation cannot differentiate between the good and bad features that contribute to that result.

b Actual diaphragms of a turbine under construction can be tested and their relative performance in the turbine predicted. The diaphragms are tested by blowing three or five nozzle passageways preceded by their proper "preliminary conditions." Diaphragms set up in this way have had changes made in the nozzles while on the test stand and efficiency tests made after each change. The whole diaphragm was then altered to the most efficient condition and the gains indicated confirmed by water rates on the turbine.

c Nozzles, buckets, etc. are tested by measuring the loss directly, that is, the distance between 95 and 100 per cent. Other methods measure the effect from 0 to 95 per cent and take the result from 100 per cent to find the loss. Consequently the air test gives highly accurate differentials of values of efficiency that are near 100 per cent.

d The models for test can be made cheaply and quickly from easily worked materials like wood, plaster, and white metal, and slight alterations made with solder or plaster. With a new feature of design it is no longer necessary to follow a "hunch," but instead a model can be construeted and tested within a week, and in almost all cases a definite answer can be given as to how much gain or loss will be caused by the change. This feature is of immense value in developing an art like turbine design, where considerable time separates conceived ideas and test results and where in most cases there could be no comparable test results because of the many new features in every succeeding design.

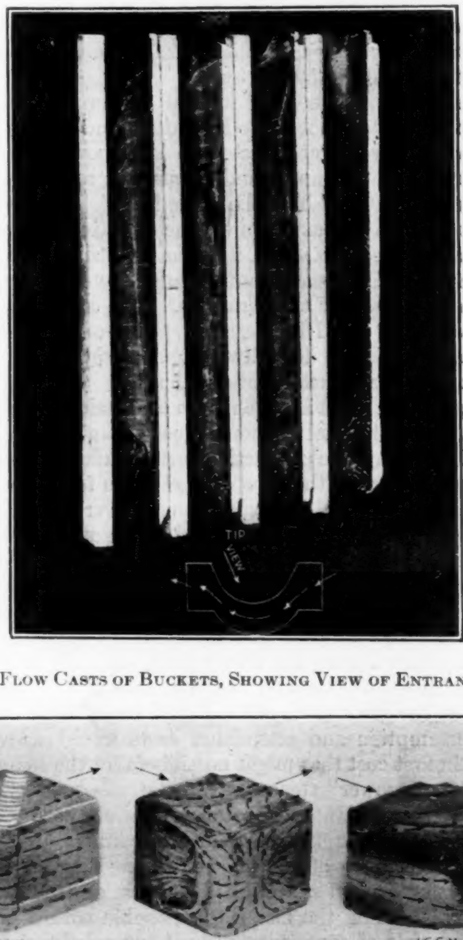


FIG. 14 FLOW CASTS OF BUCKETS, SHOWING VIEW OF ENTRANCE FLATS

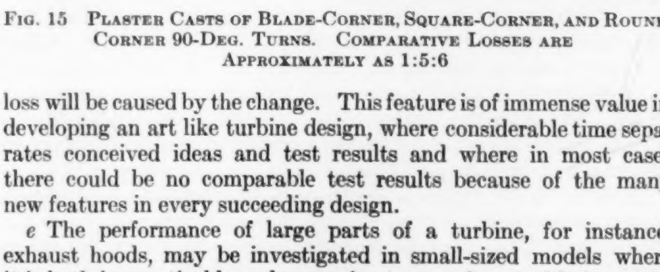


FIG. 15 PLASTER CASTS OF BLADE-CORNER, SQUARE-CORNER, AND ROUND-CORNER 90-DEG. TURNS. COMPARATIVE LOSSES ARE APPROXIMATELY AS 1:5:6

e The performance of large parts of a turbine, for instance, exhaust hoods, may be investigated in small-sized models where it is both impracticable and expensive to experiment with the actual turbine.

f This method gives an independent check on results obtained by other methods of testing, such as steam reaction-nozzle tests and water-rate tests on turbines.

In conclusion, it should be pointed out that, while all of the foregoing sounds so very simple and straightforward, nevertheless a few isolated experiments are misleading and dangerous. For instance, nozzle and bucket action are so interrelated that tests of either one alone may give wrong conclusions. Therefore a background of all the previous work done, the eleven hundred models tested, has to be freely drawn upon in order properly to design models for test and in order correctly to interpret test results.

The Diesel Engine in Small and Medium-Sized Power Plants

By Ray C. Burrus,[1] St. Louis, Mo.

In recent months a large part of the interest and attention taken in Diesel engines has been focused on units of large sizes and in central stations made up of a number of large units. In the technical press there have appeared a number of very instructive articles dealing with the progress made in designs of engines of upwards of 2000 b.hp. Some very detailed articles, including estimates of operation and fixed capital charges, have been printed, the subject of which, for large plants, has been the utility of installations totaling 5000 to 50,000 kw.

Engineers, like members of any of the professions, naturally desire to prophesy and look into the future, and no one can dispute the value of the research devoted to large-power Diesel engines. The burden of many papers and discussions referred to has been, "The day of the 10,000-b.hp. Diesel is here." Up to the present time, however, so far as we are concerned in this country, the 10,000-b.hp. or even 5000-b.hp. full-Diesel is still on the blueprints, even though the European manufacturers have had signal success in developing Diesels of these ratings. The conjectures made as to the functioning of a Diesel central station of 20,000-kw. rating, made up of five units of 4000 kw. each, cannot be far from what will be realized when such plants are built.

The large steam plant is much more economical than the smaller ones, and while the fuel economy does not at all compare with Diesel fuel economy, the production cost per kilowatt in many cases is as low or lower than the prospectuses claim for the equally large Diesel plant. It should be remembered, nevertheless, that in the case of large stand-by stations there is less reason for steam supremacy. From the standpoint of the Diesel sales engineer, it is difficult to understand why "superpower" Diesels have not long been adopted for stand-by duty. Idle steam stations have comparatively enormous fuel consumption and maintenance costs that could be entirely eliminated were the Diesel used, since for it there are no stand-by charges whatsoever. On the face of the problem, it is evident that the great savings the Diesel would assure in the items of fuel consumption and attendance costs would easily offset any difference in first cost that might possibly favor the steam plant.

In the "superpower" steam central station—such as the United Electric's Cahokia plant, for instance—the ultimate cost per unit output largely offsets the particular advantage that the Diesel engine has in economy of fuel consumption. It appears, then, that the giant steam central station is taking care of itself in the matter of economy, utilizing the last B.t.u. possible within the practical limits of its cycle of conversion of heat energy of fuel to electrical energy. But the statistics of the U. S. Department of Interior show that the average power plant in this country is an installation of about 200 hp. Further, these statistics state that this "average" power plant uses eight times the fuel per unit output that the largest central stations do. Clearly, then, the field for economy in power production lies in the small and medium-sized generating plant. So far as the smaller—the "average"—power plant is concerned, the Diesel engine offers the simplest solution to the problem of attaining minimum production costs.

In order to investigate the utility of the installation of Diesels in the medium-sized central station, it is interesting to review the "indictment" that may be brought against the "average" steam plant.

One hundred and twenty pounds of coal of representative quality contains heat units equivalent to 660 hp-hr. Even the large central station in utilizing the heat of this weight uses an additional 680 lb. from which no return is derived. This is a very poor showing, considering the elaborate layout and costly equipment of the large station. However, the little steam plant presents a picture of far greater waste. With its poor load factor as well as much less efficient equipment, throwing away heat through the stack, in the ashpit, through the steam pipes, and in the engine, it wastes 1880 lb. of coal for every 120 lb. actually utilized. The ratio of waste to utilization is very nearly 16 to 1.

It is admitted that even the small steam plant can show improvement in economy provided certain elaborate and expensive changes are made. There are on the market many types of auxiliary equipment and apparatus, the adoption of which will no doubt reduce the cost of power per unit generated, but this material necessarily adds to the maintenance expense of the plant as well as to the investment and overhead. There is a limit of efficiency, however, which cannot be exceeded no matter how much improvement or redesign is incorporated.

The waste of 1880 lb. of coal for every 120 lb. actually utilized gives the "average" steam plant an overall efficiency of less than 6 per cent. This measure is made from the coal pile to the bus bar. To refer to engine efficiency is not a fair or even accurate measure of the performance of the steam plant. Conversely, when the efficiency of the Diesel engine is noted as being 30 to 33 per cent, it is on the same scale as the "coal pile-bus bar" measure, for the Diesel engine is a power unit complete within itself, and in the single unit the heat energy of the fuel is transformed into electrical or mechanical energy by the generator or pulley. There are no power-consuming auxiliaries in the Diesel plant. The long line of energy transformation of the steam plant with its inherent losses that cannot be overcome or lessened, is not to be found in the Diesel installation.

The waste of coal is not the only waste of the small steam plant. While this waste is the largest, there are others of no less importance in their effect on the production cost of the steam station. Man power is wasted, and this increases power costs as markedly as coal waste. An engineer and fireman for each shift represent the minimum personnel permitted in the average station. The number of men employed increases where plants of more than 200 hp. are considered. The Diesel engine, on the other hand, is a one-man unit; in fact, one competent operator can successfully care for the operation of two or more units, depending, of course, on their size and the condition of the load.

Maintenance, too, must be considered in determining the losses of small and medium-sized plant operation. The steam-plant installation includes much apparatus in addition to the primary equipment that requires regular and frequent overhauling. The best firebox lining has to be renewed and the best engine packing must be replaced. The maintenance record of any steam plant gives a large list of material the inherent nature of which is such that it wears and disintegrates.

Statistics without limit may be offered to one interested in the question, and it is almost a guarantee that where the Diesel equipment has been carefully selected, particularly as to size and number of units as well as manufacture, and where the engines have been operated in an intelligent manner, there will be found an efficient power plant—a central station producing power at a cost considerably below that of a steam plant of equal rating.

The following points should be considered in comparing a Diesel installation and a steam plant of the same brake-horsepower rating:

1 First cost of complete plant—engines, electrical equipment, building and installation—is, more often than not, in favor of the Diesel.

2 Due to the direct line of energy transformation—fuel to electric power—the overall efficiency of the Diesel gives the lowest production cost per unit output.

3 Diesel maintenance is found to be less on account of the fewer number of parts the nature of which makes them subject to wear and disintegration, as compared to steam-plant equipment.

4 Diesel engines are one-man units.

5 Fuel, lubricating-oil, and circulating-water requirements of the Diesel are small fractions of those for complete steam plants, resulting in lower cost per item as well as in saving in storage space.

6 Since economy is largely independent of unit size, the Diesel central station need never be too greatly over-powered, and individual units may be added as the power demand increases.

7 For small and medium-sized stations such as are required for cities of approximately 30,000 and less, the present-day Diesel is the ideal prime mover, best meeting the requirements for economical and dependable power service.

[1] Engineer, Diesel Division, Fulton Iron Works Co.

Extracts from a paper read before the St. Louis Section of The American Society of Mechanical Engineers, April 25, 1924.

A Review of Recent Applications of Powdered Coal to Steam Boilers

By HENRY KREISINGER,[1] NEW YORK, N. Y.

This paper gives a brief statement of the trend of the development for the past two years of the application of powdered coal as a fuel for making steam. It includes treatment of developments in furnaces, driers, and mills. Test results are given from boilers and mills in six central stations using pulverized coal as fuel. The author also discusses mill capacities for various grades of coal.

THE last three years have shown a marked increase in the application of powdered coal to steam boilers. At present no important power plant decides on the coal-burning equipment without making a thorough investigation of the possibilities of powdered coal. For large stations and for large steam-generating units the indirect system seems to possess an advantage over the direct-firing system and is generally favored for this kind of service. On the other hand, direct firing seems to have some advantages in small industrial plants and small boiler units. This paper deals largely with the indirect system of firing.

The trend in the development in the various parts of the powdered coal equipment is outlined in the following paragraphs.

Furnace

Powdered coal gives high efficiency because the coal can be burned almost completely with very low excess air. However, low excess air causes high furnace temperature, which in turn causes fusion of ash and erosion of furnace lining. Many of the first attempts to burn powdered coal failed because of the excessive erosion of the furnace lining. Another cause of early failures was the difficulty of removing fused ash from the furnace. A large part of the ash was sprayed in a molten state on the walls and bottom of the furnace. The molten ash sprayed over the walls ran down, washing the brick along with it, and accumulated in a puddle of molten slag at the bottom. This slag could not be removed without cooling the furnace and mining the slag out with picks. In designing a furnace for burning powdered coal there are two problems: (*a*) The prevention of the erosion of the walls; and (*b*) easy removal of the ash deposited at the bottom of the furnace.

At present, the trend of the development of the furnace is toward nearly complete water cooling. This apparently is a positive solution for the above two problems. Water-cooled side walls are now used in addition to water screens over the bottom and back wall of the furnace. Fig. 1 shows a section through one of the last four furnaces now being installed at the Cahokia Power Station. This furnace has a water screen over the bottom and the rear wall, and fin-tube side walls. All these water-cooled tubes are connected into the circulation of the boiler, so that they really form a part of the boiler. This is a natural development in the design of furnaces. Powdered coal can never be a complete success until the boiler is built around the furnace.

For greatly reducing the abrasion on the furnace walls, the hollow-wall construction has met with considerable success, especially with coal whose ash melts at a comparatively high temperature. In this hollow-wall construction the walls are built with channels between the furnace lining and the outer wall, and through these channels 60 to 80 per cent of the air needed for combustion is passed before it enters the furnace. The air passing through the hollow walls cools the furnace lining and greatly reduces its erosion by the molten ash. Many furnaces of this design are in use and are meeting with considerable success. However, it appears that the water-cooled furnace such as shown in Fig. 1 is to be preferred where high ratings are desired and the coal has very fusible ash. One form of hollow-wall construction is shown in Fig. 2.

The hollow-wall construction has one commendable feature. No air inlets lead directly from outside into the furnace, through which a flame might puff back into the boiler room and ignite an accidentally caused dust cloud. In the hollow-wall construction the air ports supplying air for combustion open into horizontal air channels. These usually pass half-way around the furnace, so that the flame puffing out of the furnace would have to travel 30 to 40 ft. before reaching the outside of the setting. This feature makes powdered-coal furnaces safer, and hollow-wall construction also could be applied at least to some extent to water-cooled furnaces in order to make the operation of these furnaces safer.

It is frequently pointed out that pulverized coal requires large furnaces. This is undoubtedly true if the powdered-coal furnace is compared to the old-type stoker installations which usually have a furnace with a very small combustion space. However, when the comparison is made with the modern stoker furnace, the difference in size is not so great. In recent stoker installations attention is

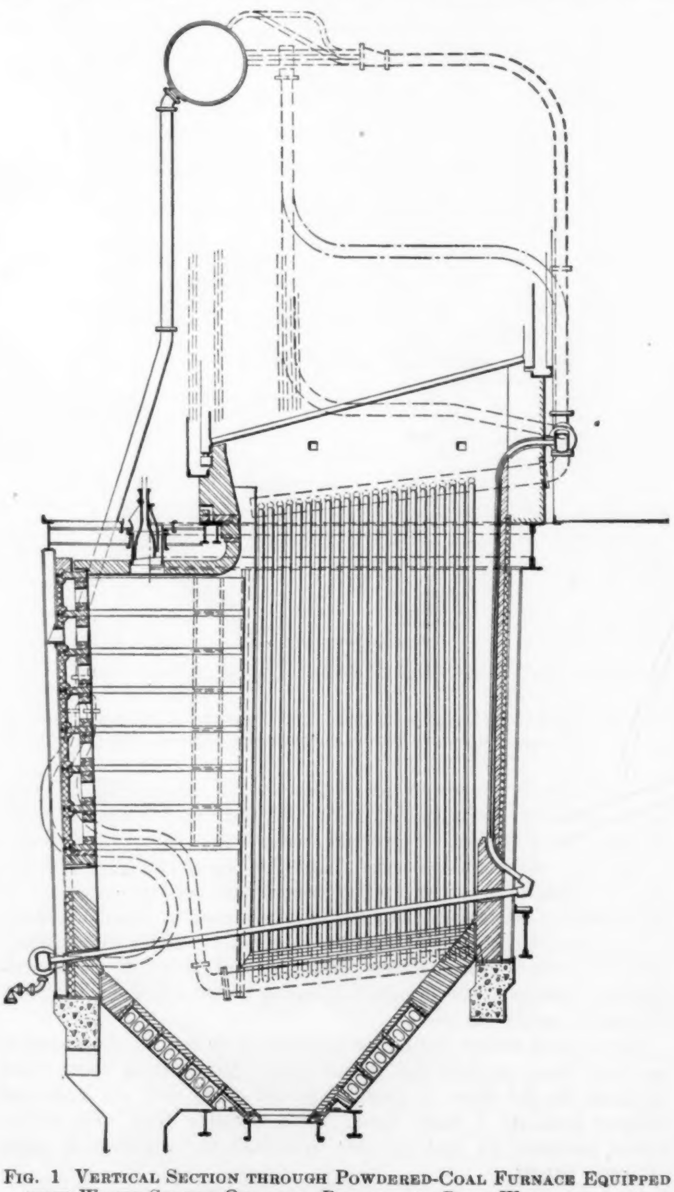


Fig. 1 Vertical Section through Powdered-Coal Furnace Equipped with Water Screen Over the Bottom and Rear Wall, and also with Fin-Tube Side Walls

(Babock & Wilcox cross-drum boiler of 18,010 sq. ft. of heating surface at Cahokia Station, Union Electric Light and Power Company, St. Louis, Mo. This is the latest design.)

[1] Research Engr., Combustion Engrn. Corp. Mem. A.S.M.E.

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given to proper design of the furnace and we find stoker installations with 20 to 22 ft. between the stoker and the boiler tubes.

Powdered-coal furnaces are made large for two reasons. First, to obtain complete combustion; second, to avoid impingement of the flame against the furnace walls, especially with the refractory-lined furnace.

Powdered coal is burned while in suspension in the air. The particles of powdered coal require from one to two seconds to burn almost completely. A large furnace must therefore be provided to permit these particles of coal to stay from one to two seconds in the combustion space. References are sometimes made to locomotive furnaces burning pulverized coal successfully, and to the fact that locomotive furnaces are much smaller than furnaces used in the stationary boilers. However, it must be remembered that in the locomotive powdered coal usually competes with hand

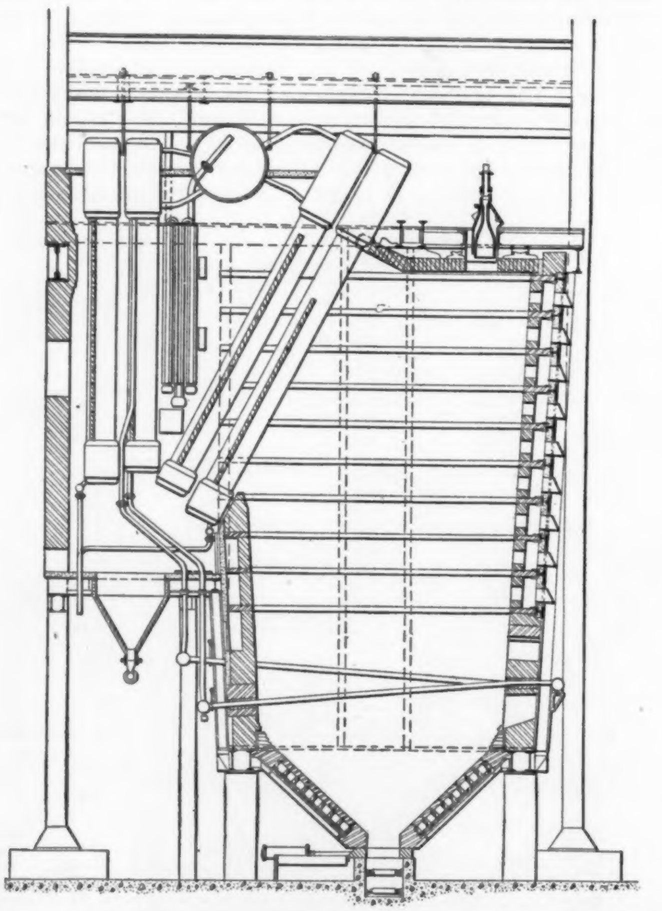


Fig. 2 Bigelow-Hornsby Boiler, 12,660 sq. ft. of Heating Surface United Railways of Providence, Providence, R. I.

firing, which is comparatively inefficient. In locomotives as much as 20 per cent of the coal fired on the grate may leave the stack in the form of sparks. Powdered coal has therefore a much larger margin in efficiency over the hand-fired locomotive. The locomotive furnace is entirely water cooled and contains little or no refractory to be destroyed by flame impingement. In the central-station practice powdered coal has a smaller margin in efficiency over the well-operated stoker furnaces, and therefore powdered-coal furnaces must be designed to get a better efficiency than the stoker to justify its use.

The second reason for larger furnaces is to reduce the impingement of flame against the refractories. More elbow room must be made for the flame so that it will not gouge into the walls and destroy them in a short time. It is possible that with water-cooled furnaces we may be able to reduce the combustion space to some extent.

Drier

Some coals require drying in order to make them pulverize easily, to facilitate conveying, and to make feeding of pulverized coal into the furnace more uniform. Other coals may be pulverized and fed to the furnace without drying. In general, coals from the Appalachian and Eastern coal fields may be pulverized and burned without drying. Coals from the Illinois and the Western coal fields must be partly dried before pulverization.

The trend in the development of coal driers is toward a small drier that will dry coal to a sufficient extent as the coal moves toward the mill. Such driers are built in the form of enlarged coal chute, and the coal is dried as it passes through the drier either by waste gases from the boilers, or by exhaust steam. Such driers extract from two to four per cent moisture. Beside abstracting moisture, they preheat the coal, so that when it gets into the mill and is pulverized, it loses moisture readily, and part of the moisture is discharged from the mill system through the mill vent.

The Cahokia station is equipped with driers of this type, using flue gases from the boiler for drying. The gases enter the driers at from 300 to 400 deg. fahr. and leave them at a temperature of 150 to 200 deg. The coal is heated to about 175 deg. fahr. and passes directly into the pulverizers which are located under the driers. Under these conditions of temperature, the driers may abstract 2 per cent moisture, while the mills abstract 6 per cent moisture from the coal. The coal entering the driers may contain 12 per cent moisture, while the coal leaving the mills may contain only 4 per cent moisture.

Driers using flue gases from the boilers for drying are adaptable to plants where the coal-preparation room is so close to the boiler plant that the gas ducts are not long. The amount of air used in this type of drier is about 3 lb. of gas per pound of coal dried. In other words, about one-quarter of the boiler flue gases is used for drying purposes. These driers are also adaptable only for plants where the flue-gas temperature is not lower than 300 deg. fahr. With plants having economizers which reduce the temperature of the gases below 300 deg. fahr., driers of this kind cannot be used.

In installations having the preparation room distant from the boiler plant, and in plants where economizers are used, a steam drier possesses an advantage over the flue-gas drier. This drier is of the same general design as the flue-gas drier, but the coal passages are made of steam-heated grids. As the coal passes through the drier it is heated and the moisture is partly evaporated. A small amount of air is drawn through the coal, and this air carries the water vapor away. The amount of air used for this purpose is about one pound of air per pound of coal. The velocities are so low that no noticeable quantity of dust is drawn out with the air. In both types of driers more moisture is driven from the coal if the coal is of a smaller size; that is, coal passing through a $^1/_4$-in. screen will dry better than coal passing through a $1^1/_2$-in. and over a $^1/_2$-in. screen.

Mills

In the development of mills for large central stations the trend is decidedly toward higher capacity. Most of the mills at present used in central stations have a capacity of from 5 to 9 tons per hour. Some mills are now being installed which have a capacity of from 15 to 18 tons per hour. The demand seems to be for a mill of about 50 tons capacity. The mills used at present are of the rolling type; that is, the coal is pulverized by rolling a metal roller or ball over the coal and in that way crushing it. A real impact mill is looked up to as having the possibility of being developed into a machine of high capacity, low power consumption, and small wear.

Results of Boiler Tests

Tables 1 to 7 give the results of seven series of boiler tests made at six different plants. The plants vary in size from an industrial plant with a unit of about 8000 sq. ft. of heating surface, to a central station with a unit of 18,000 and 26,000 sq. ft. of heating surface. These tests may therefore be considered as fairly representing the field of powdered-coal application for making steam. Descriptions of the steam-generating units on which the tests were made are given in later paragraphs. The tests were made by trustworthy engineers and most of the results are accurate within ±2 per cent, and some of them within ±1 per cent. The author witnessed practically all of the tests reported in this paper.

The accuracy of the tests is also indicated by the heat accounts, particularly by the last items—radiation, and errors and unac-

TABLE 1 RESULTS OF BOILER TESTS AT CAHOKIA POWER PLANT, UNION ELECTRIC LIGHT AND POWER COMPANY APRIL AND MAY, 1924

(Babcock & Wilcox cross-drum boiler, 18,010 sq. ft. of heating surface)

Test No.	2	3	4	5	6	7	8
Duration, hr.	25.35	21.88	25.48	20.20	23.05	24.18	10.80
Coal as fired							
Moisture, per cent	7.08	6.39	7.08	5.89	5.63	6.82	6.77
Ash, per cent	11.47	11.82	11.40	11.04	11.38	11.06	11.38
B.t.u. per lb.	11673	11553	11509	11802	11790	11713	116[illegible]2
Fired per hour, lb.	8991	13267	8105	16187	11256	13161	17525
Per cu. ft. of combustion space per hr., lb.	0.77	1.13	0.69	1.38	0.96	1.12	1.49
Ash							
Comb. in furnace ash	0.2	......	......	......	......	......	......
Comb. in flue dust	4.8	3.4	4.0	5.1	1.8	2.8	3.0
Water, lb.							
Evaporated per hour	75948	104458	66286	129779	90454	107114	133763
Evaporated per lb. of coal	8.45	7.98	8.18	7.99	8.04	8.18	7.63
B.t.u. per lb. of steam	1185.4	1203.8	1187.7	1213.3	1200.3	1210.6	1222.9
Temperatures, deg. fahr.							
Air to furnace	95	91	87	81	84	80	82
Air to feeders							
Gases leaving boiler	483	520	474	564	502	527	589
Feedwater	197	199	194	200	197	198	203
Superheated steam	670	707	668	727	697	718	750
Pressures, lb. per sq. in., abs.							
Superheater	330	332	328	334	330	331	332
Drafts, in. of water							
Furnace	0.13	0.15	0.08	0.34	0.14	0.18	0.22
Uptake	0.37	0.70	0.20	0.47	0.56	0.80	1.60
Pressure feeder air	9.2	12.2	11.3	17.8	13.4	13.5	19.8
Analysis of gases, uptake							
CO_2	[illegible]4.7	14.7	14.4	14.1	14.5	14.7	14.0
O_2	[illegible].1	3.9	4.4	4.7	4.3	4.3	5.0
CO	0	0	0	0	0	0	0
Heat account in per cent							
Heat absorbed by boiler and superheater	85.9	83.1	83.8	82.1	81.8	84.5	79.9
Loss in dry gases	9.1	10.2	9.2	11.7	10.0	10.5	12.5
Loss in water vapor	5.1	5.4	4.9	5.0	4.8	5.0	5.0
Loss in incomplete combustion	0.6	0.5	0.5	0.6	0.2	0.3	0.4
Radiation / Errors and unaccounted for	−0.7	+0.8	+1.6	+0.6	+3.2	−0.3	+2.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 2 RESULTS OF BOILER TESTS AT RIVER ROUGE PLANT OF FORD MOTOR COMPANY, NOVEMBER AND DECEMBER, 1923

(Ladd boiler, 26,470 sq. ft. of heating surface)

Test No.	1	2	3	4	5
Duration, hours	30.58	31.00	37.07	23.82	24.03
Rating, per cent	150.4	211.3	260.0	285.9	222.9
Coal as fired					
Through 60 mesh, per cent	97.8	96.4	96.4	97.2	98.0
Through 100 mesh, per cent	90.2	88.0	89.6	90.5	91.0
Through 200 mesh, per cent	76.2	72.8	73.3	76.0	77.0
Moisture, per cent	2.0	3.2	3.2	3.4	3.2
Ash, per cent	9.94	7.21	9.30	5.57	6.89
B.t.u per lb.	13237	13299	13101	13467	13299
Fired per hour, lb.	12912	17723	21750	22900	18270
Per cu. ft. of combustion space per hr., lb.	0.98	1.34	1.65	1.74	1.39
Ash					
Comb. in furnace refuse	0	0	0	0	0
Comb. in flue dust	......	4.0	12.0	34.8	12.0
Water, lb.					
Evaporated per hour	106419	148406	183065	200116	156567
Evaporated per lb. of coal	8.22	8.38	8.42	8.74	8.57
B.t.u. per lb. of steam	1252	1263	1260	1267	1263
Temperatures, deg. fahr.					
Air to furnace	90.3	77.8	77.3	83.8	84.1
Air to feeders	90.3	77.8	77.3	83.8	84.1
Gases leaving boiler	558	611	635	654	615
Feedwater	121.4	116.6	119.6	105.3	111.0
Superheated steam	642	653	654	640	643
Pressures, lb per sq. in., abs.					
Superheater	242.5	244.2	239.5	237.8	246.4
Drafts, in. of water					
Furnace	0.25	0.18	0.31	0.47	0.35
Uptake	1.28	1.75	1.89	2.15	1.63
Pressure feeder air	4.5	7.5	7.5	7.6	9.0
Analysis of gases, uptake					
CO_2	11.6	12.9	15.3	14.6	13.5
O_2	6.5	5.3	3.1	3.9	5.5
CO	0	0	0	0	0
Heat account in per cent					
Heat absorbed by boiler and sup.	77.8	79.6	80.9	82.2	82.0
Loss in dry gases	13.4	13.6	12.2	12.8	13.1
Loss in water vapor	4.0	4.4	4.3	4.3	4.2
Loss in incomplete combustion	0.5	0.5	0.9	1.6	0.6
Radiation / Errors and unaccounted for	+4.3	+1.9	+1.7	−0.9	+0.1
Total	100.0	100.0	100.0	100.0	100.0

counted for. In some cases the radiation is computed as a separate item, so that the line headed "errors and unaccounted for" really shows the errors made in collecting the data and the accuracy of the test. This method was applied particularly to the tests made at the West Penn Power Company's plant at Springdale, Pa., because at this plant the coal and water were weighed by Richardson automatic scales. These scales were carefully calibrated, and during the test were closely watched. The last item in the heat account indicates that the automatic scales did very well. The tests are presented in this paper because of the high rating that was obtained with the boiler, particularly on test No. 7. This test was started with a running start; that is, there had been no fire in the furnace for six hours when the test was started, although

TABLE 3 RESULTS OF BOILER TESTS OF BOILER NO. 18, PLANT NO. 3, ROCHESTER GAS AND ELECTRIC COMPANY, JULY AND AUGUST, 1924

(Bigelow-Hornsby boiler, 8750 sq. ft. of heating surface)

Test No.	5	6	7	8	9	10	11	12	13
Duration, hours	23.15	22.93	19.25	21.73	21.95	13.98	14.93	14.92	15.05
Rating, per cent	157	170	199	178	180	163	173	177	166
Coal as fired									
Through 60 mesh, per cent	.....	.....	94.0	93.6	94.9	94.5	97.0	96.3	94.6
Through 100 mesh, per cent	83.0	86.8	88.1	87.6	88.2	89.0	89.3	89.5	87.7
Through 200 mesh, per cent	59.1	61.4	59.1	58.4	60.2	60.2	62.6	66.4	61.8
Moisture, per cent	2.6	2.9	3.2	3.0	3.1	3.6	2.9	3.4	4.6
Ash, per cent	8.5	9.8	9.2	8.4	10.3	10.6	11.0	10.3	9.7
B.t.u. per lb.	135[illegible]5	13170	13240	13485	13120	13120	13110	13135	13235
Fired per hour, lb.	4212	4808	5588	4797	5020	4775	4912	4794	4536
Per cu. ft. of combustion space per hr. lb.	1.00	1.15	1.33	1.14	1.20	1.14	1.17	1.14	1.08
Ash									
Comb. in furnace refuse	0.3	4.5	.....	1.3	1.9	1.4	1.4	1.4	1.4
Combustible in flue dust	13.8	6.2	21.0	21.5	18.2	18.0	14.9	13.1	13.6
Water, lb.									
Evaporated per hr	39969	43315	50747	45182	45856	41844	44379	45566	42670
Per lb. of coal	9.44	9.01	9.10	9.42	9.13	8.76	9.03	9.50	9.41
B.t.u per lb. of steam	1210	1206	1204	1204	1206	1198	1194	1191	1198
Temperatures, deg. fahr.									
Air to furnace	86	88	77	76	71	86	87	84	73
Air to feeders	142	156	143	151	142	133	143	150	143
Gases leaving boiler	540	557	577	553	562	550	552	558	574
Gases leaving econ.	342	366	370	347	363	360	363	361	377
Water to economizer	87	93	85	85	87	95	94	95	94
Water to boiler	147	147	138	137	140	151	147	147	150
Superheated steam	496	499	481	481	487	490	481	477	487
Pressures, lb. per sq. in. abs.									
Boiler	220	221	219	217	218	217	217	220	217
Superheater	206	207	207	206	207	208	207	209	209
Drafts, in. of water									
Furnace	0.03	0.05	0.08	0.05	0.04	0.05	0.05	0.04	0.05
Gas leaving boiler	0.09	0.11	0.18	0.12	0.13	0.15	0.15	0.15	0.15
Gas leaving econ.	.....	.....	0.48	.....	0.46	.....	.....	.....	.....
Analysis of flue gases									
CO_2, gas leaving boiler	14.3	14.5	15.6	15.4	14.9	14.0	13.9	14.1	14.3
CO_2, gas leaving econ.	13.0	12.9	13.8	13.5	13.1	12.7	12.8	13.0	12.8
Heat account									
Heat absorbed by boiler and superheater	80.6	78.8	78.9	80.5	80.2	76.3	78.6	82.4	81.2
Heat absorbed by boiler superheater and economizer	84.8	82.5	82.5	84.1	83.9	80.0	82.2	86.1	85.1
Loss in dry gases	6.4	7.0	6.8	6.5	6.6	6.8	6.9	6.9	7.6
Loss in water vapor	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Loss in incomplete combustion	1.3	1.0	3.1	3.1	3.2	1.8	1.8	1.8	1.8
Rad. errors and unaccounted	+3.2	+5.2	+3.3	+2.0	+2.0	+7.1	+4.8	+0.9	+1.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4 RESULTS OF TESTS AT SPRINGDALE STATION, WEST PENN POWER COMPANY, DECEMBER, 1923

(Babcock & Wilcox cross-drum boiler, 15,326 sq. ft. of heating surface)

Test No.	2	3	4	5	6	7
Duration, hours	24	24.07	23.37	22.58	45.92	23.05
Rating, per cent	213.8	218.4	309.1	383.0	125.2	441.8
Coal as fired						
Through 60 mesh, per cent						
Through 100 mesh, per cent	82.93	92.74		86.72	85.16	87.67
Through 200 mesh, per cent	62.93	77.95		66.58	63.72	64.68
Moisture, per cent	1.37	1.12	1.47	1.84	1.51	1.51
Ash, per cent	11.26	12.23	11.51	11.35	11.85	9.45
B.t.u. per lb.	13246	13114	13356	13269	13244	13469
Fired per hour, lb.	10183	10448	15076	18890	5865	22315
Per cu. ft of combustion space per hr., lb.	0.82	0.84	1.216	1.52	0.47	1.80
Water, lb.						
Evaporated per hour	89158	91516	127171	155314	53390	177383
Evaporated per lb. of coal	8.75	8.76	8.44	8.22	9.10	7.95
B.t.u. per lb. of steam	1232.3	1227.2	1248.5	1267.4	1205.5	1280.3
Temperatures, deg. fahr.						
Air to furnace	59	56	61	52	68	43
Air to feeders	141	141	133	127	135	104
Gases leaving boiler	555	556	608	665	494	691
Feedwater	94.	98.	95.	93.	94.	88.
Superheated steam	571	570	602	633	527	647
Pressures, lb. per sq. in. abs.						
Boiler	321	323	327	336	320	344
Superheater	318	320	322	331	319	337
Drafts, in. of water						
Furnace	.05	.05	.15	.24	.04	.30
Uptake	.42	.38	.94	1.62	.10	2.22
Pressure feeder air	10.2	8.9	15.0	17.1	8.5	19.2
Analysis of gases, uptake						
CO_2	12.9	13.6	13.5	13.2	12.5	13.1
O_2	6.1	5.6	5.5	5.7	6.7	5.5
CO	.06	.05	.08	.08	.01	.16
Heat account in per cent						
Heat absorbed by boiler and superheater	81.4	81.9	78.9	78.5	82.8	75.5
Loss in dry gases	12.9	12.4	13.5	15.5	11.6	16.6
Loss in water vapor	4.4	4.4	4.5	4.7	4.3	4.7
Loss in incomplete combustion	1.0	1.0	1.5	2.0	1.0	2.5
Radiation	0.7	0.7	0.5	0.4	1.4	0.3
Errors and unaccounted for	−0.4	−0.4	+1.1	−1.1	−1.1	+0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

the boiler was kept on the line during this period. When the test was started the burners were lit, and within less than five minutes the boiler was operating at 300 per cent rating, and soon after that was brought up to above 400 per cent rating. The average for the run, which lasted 24 hours, was 442 per cent.

In the heat accounts, attention is called to the item "Loss in incomplete combustion." This item includes the combustible in the flue dust, which is by far the largest loss due to incomplete combustion. In many tests with powdered coal this source of

TABLE 5 RESULTS OF TESTS AT THE PLANT OF PENN SALT CO., WYANDOTTE, MICH., JULY AND AUGUST, 1923

(Babcock & Wilcox cross-drum boiler, 8220 sq. ft. heating surface)

Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Duration, hr.	23.57	24.72	22.77	21.73	22.72	24.78	24.22	23.30	23.65	24.92	16.07	24.43	23.83
Rating, per cent	174.2	174.2	125.0	125.0	164.3	164.3	205.8	101.0	201.0	201.0	221.0	189.5	211.6
Coal as fired													
Through 50 mesh, per cent	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.0	99.9	99.1	99.9
Through 100 mesh, per cent	95.3	94.9	96.1	96.8	97.2	97.3	97.7	97.8	96.7	96.7	95.5	93.7	96.1
Through 200 mesh, per cent	71.1	28.5	70.7	66.6	77.0	76.3	77.8	78.1	76.3	73.8	72.0	73.6	73.1
Moisture, per cent	2.4	2.1	1.8	2.1	1.9	2.4	2.1	1.8	2.0	1.9	1.6	5.6	2.6
Ash, per cent	15.1	13.9	14.2	13.4	12.9	15.5	14.0	13.9	13.6	13.1	13.3	14.3	13.5
Heat value, B.t.u.	12385	12518	12383	12530	12874	12276	12522	12702	12783	12889	12710	12116	12552
Coal per hr. lb.	4683	4560	3285	3122	4316	4182	5375	5585	5300	5390	5980	5270	5820
Coal per hr. per cu. ft. comb. space	1.39	1.36	0.98	0.93	1.28	1.25	1.60	1.66	1.59	1.61	1.78	1.57	1.73
Ash													
Combustible in furnace ash, per cent	5.0	1.4	2.5	2.2	1.2	4.0	3.8	3.7	4.0	4.8	9.15	......	9.4
Flue dust, per cent	10.2	10.2	10.5	8.7	11.8	11.8	......	......	15.8	15.8	15.2	......	16.9
Calculated combustible loss	1.3	1.1	1.1	0.9	1.1	1.5	1.7	1.7	1.7	1.6	1.8	2.0	1.9
Water													
Per hour, lb	40700	41030	29810	29300	39650	37580	47950	46900	45950	47.480	51350	44400	50800
Per lb. coal as fired	8.71	9.00	9.08	9.38	9.18	8.98	8.93	8.41	8.59	8.82	8.59	8.43	8.74
Temperatures, deg. fahr.													
Outside air	80.1	79.8	69.8	69.0	71.0	67.2	72.1	76.6	78.3	75.2	74.6	72.9	72.6
Air to furnace	89.9	90.1	81.5	80.1	83.1	80.2	83.0	89.8	90.0	87.2	86.7	86.6	86.0
Flue gas	459.3	446.3	409.4	414.6	476.9	475.2	524.5	545.2	546.0	555.4	563.6	550.7	504.2
Feedwater	102.0	101.7	101.4	100.0	100.5	99.7	100.2	102.9	103.0	102.2	101.4	103.1	145.0
Superheated steam	458.5	462.4	441.5	440.4	457.2	453.7	472.0	474.4	479.3	480.9	477.0	474.6	473.2
Pressure, lb. per sq. in. absolute													
Steam pressure	217.8	218.2	214.9	214.1	218.8	217.0	220.5	219.6	220.5	221.7	215.7	220.9	219.0
Draft and air pressures, in. of water													
Draft at damper	0.37	0.36	0.16	0.13	0.34	0.23	0.57	0.56	0.62	0.61	0.77	0.60	0.66
Draft at furnace bottom	0.26	0.25	0.12	0.00	0.23	0.18	0.29	0.31	0.35	0.34	0.40	0.35	0.44
Draft under arch	0.14	0.15	0.06	0.06	0.17	0.12	0.24	0.22	0.25	0.24	0.31	0.25	0.42
Pressure of air at feeders	4.8	5.5	5.6	5.4	6.0	5.5	5.00	12.7	10.7	11.1	14.2	14.0	15.3
Flue gas													
CO_2, per cent by vol.	14.54	14.31	15.43	15.55	14.50	15.40	13.64	13.83	13.72	13.34	13.15	12.64	13.83
O_2, per cent by vol.	4.50	4.82	3.62	3.37	4.51	3.80	5.53	5.40	5.52	5.92	6.02	6.76	5.97
CO, per cent by vol.	0	0	0	0	0	0	0	0	0	0	0	0	0
Excess air, per cent	27.2	29.8	20.8	19.2	27.2	22.2	35.6	34.6	35.5	39.3	40.2	47.3	39.7
Heat account, per cent													
Heat absor. by boiler and superheater screen	82.5	84.1	85.3	87.1	83.6	85.8	84.3	78.2	79.4	8.00	79.8	82.1	79.8
Heat lost, per cent													
Dry flue gas	7.6	7.3	6.4	6.3	7.9	7.7	9.3	9.5	9.6	10.0	10.4	10.7	9.0
Hydrogen and moisture in coal	4.6	4.5	4.6	4.5	4.5	4.6	4.6	4.6	4.6	4.6	4.6	5.1	4.6
Combustible in ash and refuse	1.5	1.3	1.2	1.0	1.3	1.8	2.0	2.0	1.9	1.8	2.1	2.3	2.2
Radiation	1.7	1.0	2.4	2.4	1.7	1.8	1.4	1.5	1.5	1.5	1.3	1.5	1.4
Unaccounted for and errors	+2.1	+1.8	+0.1	−1.3	1.0	−1.7	−1.6	+4.2	+3.0	+1.2	+1.8	−1.7	+3.0
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 6 RESULTS OF BOILER TESTS AT THE PLANT OF THE UNITED RAILWAYS OF PROVIDENCE, AUGUST, SEPTEMBER AND OCTOBER, 1924

(Bigelow-Hornsby boiler, 12,660 sq. ft. of heating surface; New River coal)

Test No.	12	13	14	15	16	17	18	19	20
Duration, hr.	14.55	12.27	15.83	13.15	13.87	12.73	13.02	16.13	15.25
Rating, per cent	178	324	188	229	241	228	190	262	175
Coal as fired [1]									
Moisture, per cent	3.0	2.9	2.6	4.8	6.4	5.5	3.1	3.1	2.6
Ash, per cent	6.0	6.8	7.2	6.7	5.6	5.4	8.1	7.3	6.3
B.t.u. per lb.	14075	13945	14000	13790	13330	13464	13732	13836	14171
Fired per hour, lb.	6153	11380	6181	7800	8509	8109	6562	9354	5996
Per cu. ft. of combustion space per hr., lb.	0.65	1.20	0.65	0.82	0.90	0.85	0.69	0.99	0.63
Water									
Evaporated per hr., lb.	65880	117060	68920	83560	88110	83080	68560	93120	64400
Per lb. coal, lb.	10.7	10.3	11.1	10.7	10.4	10.3	10.5	10.0	10.7
B.t.u. per lb. of steam	1147	1176	1156	1167	1162	1163	1176	1192	1159
Temperatures, deg. fahr.									
Air to furnace	90	93	89	96	94	100	97	84	87
Air to feeders	137	137	130	131	130	128	124	121	118
Gases leaving boiler	520	650	520	582	572	562	573	649	524
Gases leaving econ.	256	338	258	288	269	280	269	319	254
Water to economizer	190	201	190	194	193	189	191	192	195
Water to boiler	278	317	279	298	284	285	294	304	284
Superheated steam	572	647	589	615	605	600	629	660	604
Pressures, lb. per sq. in. abs.									
Boiler	231	259	239	234	234	234	231	237	228
Superheater	222	248	231	225	228	233	228	231	224
Drafts, in. of water									
Furnace	0.03	0.19	0.02	0.05	0.04	0.09	0.04	0.09	0.01
Gases leaving boiler	0.25	0.83	0.28	0.38	0.37	0.37	0.32	0.58	0.24
Gases leaving econ.	0.70	2.26	0.73	1.07	1.09	1.09	0.89	1.53	0.75
Press. feeder air	11.2	12.1	12.4	12.8	11.3	12.1	11.8	12.6	11.8
Analysis of gas									
CO_2 leaving boiler	15.0	15.0	15.0	15.4	15.5	15.0	15.0	15.4	14.9
CO_2 leaving economizer	15.0	14.9	15.0	15.5	15.4	14.9	15.1	15.5	14.9
Heat account									
Heat absorbed by boiler and superheater	80.5	77.0	84.9	82.8	82.9	81.3	81.6	77.7	81.0
Heat absorbed by boiler, superheater and economizer	87.3	86.7	92.0	90.6	90.2	88.5	89.5	85.8	87.9
Loss in dry gases	3.7	5.4	3.8	4.2	3.9	4.1	3.8	4.1	3.7
Loss in water vapor	3.7	3.8	3.7	3.9	4.0	4.0	3.7	3.9	3.7
Loss in incom. comb.	2.6	2.5	1.2	1.3	1.6	1.5	1.3	1.7	1.1
Radiation / Errors and unaccounted for	2.7	1.6	−.7	0	.3	1.9	1.7	4.5	3.6

[1] Average fineness: Through 200 mesh, 75 per cent; through 100 mesh, 90 per cent

TABLE 7 RESULTS OF TESTS AT THE PLANT OF UNITED RAILWAYS OF PROVIDENCE, OCTOBER, 1924

(Bigelow-Hornsby boiler, 12,660 sq. ft. of heating surface; Coal: Mixture of New River and Rhode Island coal)

Test No.		35	36	38	39	41	40	42
Duration, hr.		14.98	12.47	12.10	15.60	16.35	13.55	11.43
Rating dev. by unit, per cent		157	227	272	192	261	185	220
Coal as fired								
Through 40 mesh, per cent		.....	.....	.....	99.6	.....	99.4	99.9
Through 100 mesh, per cent		.....	.....	.....	85.0	.....	87.6	89.9
Through 200 mesh, per cent		.....	.....	.....	65.4	.....	69.5	70.5
Moisture, per cent		4.7	4.5	5.9	4.4	4.1	4.5	4.6
Ash, per cent		17.4	19.3	18.7	17.8	17.7	21.1	20.7
B.t.u. per lb. of mixture		11543	11308	10997	11577	11424	10788	10808
Fired per hr., lb.	R. I.	3245	4970	5892	4103	6180	5506	6684
	N. R.	3327	4920	5940	4031	5274	2928	3371
Per cu. ft. comb. sp. per hr., lb.	R. I.	0.34	0.46	0.62	0.43	0.65	0.58	0.70
	N. R.	0.35	0.40	0.45	0.42	0.57	0.31	0.35
Water								
Evaporated per hr., lb.		57533	81265	95519	69731	92832	67180	75929
Evap. per lb. of coal, lb.		8.75	8.42	8.07	8.57	8.10	7.95	7.91
B.t.u. per lb. of steam		1155	1185	1206	1165	1192	1166	1171
Temperatures, deg. fahr.								
Air to furnace		79	83	78	79	82	83	88
Air to feeders		119	110	106	105	103	106	105
Gases leaving boiler		490	551	578	522	576	535	545
Gases leaving economizer		242	288	304	268	309	270	275
Water to economizer		188	189	188	189	197	194	196
Water to boiler		262	284	293	278	306	291	287
Superheated steam		583	639	680	610	669	615	626
Pressures, lb. per sq. in. abs.								
Boiler		234	235	239	237	239	233	237
Superheater		221	224	227	230	229	227	227
Drafts, in. of water								
Furnace		0.15	0.17	0.17	0.09	0.23	0.08	0.15
Gases leaving boiler		0.30	0.58	0.71	0.39	0.82	0.41	0.54
Gases leaving economizer		0.69	1.44	1.87	0.90	2.09	1.00	1.35
Press. feeder air		14.1	14.4	14.6	14.4	15.2	14.1	14.3
Analysis of gas								
CO_2 leaving boiler		14.0	13.9	13.8	14.1	13.8	13.9	14.6
CO_2 leaving econ.		13.9	13.7	14.0	14.3	13.8	13.8	14.7
Heat account								
Heat absorbed by boiler and superheater		82.6	81.2	80.8	79.8	76.3	78.7	78.9
Heat absorbed by boiler, superheater and economizer		88.3	88.3	88.4	86.2	84.4	85.0	84.8
Loss in dry gases		3.9	4.8	5.4	4.3	5.4	4.1	3.8
Loss in water vapor		2.9	3.0	3.2	2.9	3.1	3.3	3.3
Loss in incom. comb. / Radiation / Errors and unaccounted for		4.9	4.9	4.0	6.6	7.1	8.6	8.1

incomplete combustion is entirely neglected. With improper furnace design and poor operation the flue dust may be as black as the powdered coal that is fed to the furnace. Usually only the flue gases are analyzed, and a sample of the deposit on the bottom of the furnace may be taken and analyzed. Neither of these two may contain any appreciable amount of combustible, while at the same time a large amount of unburned carbon may be passing out of the boiler with the gases.

Table 7 gives the results of tests with Rhode Island graphitic coal, pulverized and burned in a mixture with New River coal. The tests were made at the same plant and on the same boiler as the tests presented in Table 6. The Rhode Island coal has a very low percentage of volatile matter, and the gases distilled as volatile matter are not combustible. For this reason it is practically impossible to start fires with it alone. However, in a mixture of half and half with New River coal, or even two parts of Rhode Island and one part of New River coal, the mixture ignites readily and is a practical fuel. The economic results obtained with these mixtures compare well with the results obtained when using New River coal.

Table 8 gives the results of three series of mill tests made with three different coals at three different plants. The results show

that the output of the mill varies to a large extent with the quality of the coal. With Illinois and some of the hard Pennsylvania bituminous coal the capacity of a 6-roll Raymond mill is between 5 and 6 tons. With the coals having granular structure, such as New River and Pocahontas, the capacity is as high as 9 tons per hour. It is higher with dry coal and lower with moist coal.

Reliable data on the cost of making steam with powdered coal are still meager. It is to be expected that with many powdered-coal plants in operation more data on the cost of making steam soon will become available, so that it will be possible to make a fair comparison with the cost of making steam in stoker plants.

In the past, unfair deductions for powdered coal were often made by estimating the cost of preparing pulverized coal and then comparing it with the value of the coal saved by the higher thermal efficiency of powdered coal over the stoker. All comparisons should be made on the basis of total cost of preparing and burning pulverized coal, and the total cost of burning with stokers. However, such cost can be compiled best by the operating engineers. It is hoped that some such data will be presented in the discussion of this paper. The following method of presenting cost data is suggested.

TABLE 8 RESULTS OF TESTS OF 6-ROLL RAYMOND MILLS

ILLINOIS COAL [1]

Test No.	1	2	3	4	5	6	7	8
Total mill hours	16.33	13.99	27.72	17.05	58.86	35.23	50.15	48.78
Coal per hour, tons	5.97	5.24	5.27	6.00	6.68	5.70	4.31	4.06
Moisture in coal, per cent	4.6	6.0	5.2	4.1	5.6	3.7	6.1	6.2
Kw. per hour	77.5	78.0	77.9	78.3	79.3	78.7	77.2	77.4
Power per ton of coal, kw-hr.	13.0	14.9	14.7	13.4	14.3	14.1	18.4	19.6

Average fineness of coal: Through 100 mesh 95 per cent, through 200 mesh 76 per cent.

Tests 1 to 6, dried coal; tests 7 and 8, undried coal.

PENNSYLVANIA COAL, NATRONA MINE, UNDRIED [2]

Test No.	1	2	3	4	5	6	7	8	9	10	11
Total mill hours	10.92	11.17	6.93	6.35	9.90	10.65	14.26	14.10	13.03	13.48	9.92
Coal per hour, tons	5.04	5.04	5.40	5.35	4.95	4.86	4.56	4.61	4.86	4.98	4.87
Moisture in coal, per cent	2.4	2.1	1.8	2.1	1.9	2.4	2.1	1.8	2.0	1.9	1.6
Kw. per hour	63.7	67.6	69.3	68.0	63.9	66.1	61.6	59.1	69.0	67.0	65.0
Power per ton of coal, kw-hr.	12.45	13.41	13.14	12.75	12.96	13.56	13.50	12.81	14.25	13.38	13.38

Average fineness of coal: Through 100 mesh 95 per cent, through 200 mesh 76 per cent.

NEW RIVER COAL, UNDRIED [3]

Test No.	1	2	3	4	6	7	9
Total mill hours	8.6	6.8	5.1	5.8	5.8	4.6	5.6
Coal per hour, tons	9.9	8.85	8.8	8.1	8.7	8.3	7.1
Moisture in coal, per cent	2.5	2.0	2.6	2.7	2.6	3.1	2.0
Kw. per hour	112	106	104	99	105	105	87
Power per ton of coal, kw-hr.	11.4	12.0	11.8	12.2	12.1	12.7	12.3

Average fineness of coal: Through 100 mesh 98.5 per cent, through 200 mesh 81.5 per cent.

[1] Tests at St. Joe Lead Co., River Mines, Mo., November, 1921.
[2] Tests at Penn Salt Co., Wyandotte, Mich., July and August, 1923.
[3] Tests at United Rys. of Providence, Providence, R. I., May, 1924.

COST OF BURNING ONE TON OF COAL

	Powdered-coal plant	Stoker plant
A. Operating labor............	$...........	$...........
B. Power......................	....	....
C. Maintenance................	....	....
D. Fixed charges..............	....	....

DESCRIPTION OF BOILERS AND FURNACES AND METHOD OF MAKING TESTS

The furnaces on which the tests were made were fired vertically downward, the flame turning up near the bottom, making a U-shaped path through the furnace. About 15 to 20 per cent of the air needed for combustion was supplied with the coal, another 10 to 15 per cent of the air was supplied through the burners around the nozzles, and 60 to 70 per cent through the hollow walls.

Cahokia Power Plant, St. Louis, Mo. The boiler was a Babcock & Wilcox cross-drum, 20 tubes high and 38 tubes wide, with 18,010 sq. ft. of heating surface. It was equipped with a Babcock & Wilcox superheater of 4070 sq. ft. of heating surface placed in an interdeck chamber above the sixth row of boiler tubes.

The furnace was of the hollow-wall construction with a steel casing. It was equipped with 10 Lopulco fantail burners and a water screen over the bottom and rear wall of the furnace, with 587 sq. ft. of heating surface exposed to fire. The water screen consisted of 4-in. tubes spaced 10.85 in. between centers. It was connected to the boiler drum by two 6-in. downcomers and two 8-in. risers. The combustion space above the water screen was 11,750 cu. ft. The average distance between arch and water screen was 22 ft.

The tests were made by the engineers of McClellan & Junkersfeld, Inc., and of the Union Electric Light & Power Co. Water was weighed in two special test tanks placed on a standard platform scale. Coal was weighed in the weighing tanks of the Quigley air transport as it was delivered to the bin of the test boiler. The results of the tests are given in Table 1.

The coal used was Illinois coal having the typical composition given in Table 9.

River Rouge Plant of Ford Motor Co. The results of the tests are given in Table 2. The boiler was a Ladd water-tube boiler with 26,470 sq. ft. of heating surface. It was equipped with a locomotive superheater made by the Superheater Co. and placed between the boiler tubes in the first pass of the boiler. The heating surface of the superheater was 3140 sq. ft.

The furnace was of solid-wall construction equipped with 12 Lopulco burners, six burners on each side of the boiler. There was no water screen in the furnace. The total combustion space was 13,200 cu. ft. Coal was fired vertically downward. The distance between burner arches and the bottom of the furnace was 20 ft.

The tests were made by the engineers of the River Rouge Plant in coöperation with the test engineers of Combustion Engineering Corporation.

The coal used on the tests was a mixture of two Kentucky coals from Banner Fork and Pond Creek mines, and had the typical composition given in Table 9.

Rochester Gas and Electric Co. The boiler was of the Bigelow-Hornsby type, having 8750 sq. ft. of heating surface. It was equipped with a Foster superheater of 1055 sq. ft. of heating surface, and a Sturtevant cast-iron-tube economizer with 2390 sq. ft. of heating surface.

The furnace was of hollow-wall construction with a steel casing. It was equipped with four fantail Lopulco burners and a water screen over the bottom of the furnace having 157 sq. ft. of heating surface. The combustion space of the furnace was 4200 cu. ft. above the water screen and 655 cu. ft. below the screen. The distance between the burner arch and the water screen was 26 ft.

The tests were made by the plant test engineers in coöperation with the test engineers of the Combustion Engineering Corporation. Coal and water were weighed with standard scales. The results are given in Table 3.

The coal burned was Pennsylvania Lucerne Mine coal of the typical composition given in Table 9.

Springdale Plant, West Penn Power Co. The boiler was a Babcock & Wilcox cross-drum, 15 tubes high and 42 tubes wide, the tubes being 20 ft. long. The heating surface was 15,326 sq. ft. The boiler was equipped with a Babcock & Wilcox superheater located above the first pass, and having 3860 sq. ft. of heating surface.

The furnace was of hollow-wall construction with a steel casing. It was equipped with eight Lopulco burners and a water screen over the bottom and rear wall of the furnace, and having 480 sq. ft. of heating surface. The water screen consisted of 4-in. tubes spaced 14 in. between centers and connected to the boiler drum with two 6-in. downcomers and two 6-in. risers. The distance between the burner arch and the water screen was 23 ft.

The tests were made by the test engineers of the West Penn Power Company, and the results are given in Table 4. Water and coal were weighed with Richardson automatic scales. The coal used was Pittsburgh coal. A representative analysis of the coal is given in Table 9.

Penn Salt Co., Wyandotte, Mich. The boiler was a Babcock & Wilcox cross-drum boiler, 14 tubes high and 27 tubes wide, having 8220 sq. ft. of heating surface, and was equipped with Babcock & Wilcox superheater.

The furnace was of hollow-wall brick construction, equipped with 4 Lopulco fantail burners and a water screen over the bottom of the furnace. The screen consisted of 4-in. tubes spaced $14^1/_2$ in. centers, connected to boiler drum with two 6-in. downcomers and two 6-in. risers, and having 236 sq. ft. of heating surface. The combustion space was 3360 cu. ft. The distance between burner arch and the water screen was 14 ft.

The tests given in Table 5 were made by the engineers of the Penn Salt Company in coöperation with the test engineers of the Combustion Engineering Corporation. The coal was weighed on standard scales in lots of 1000 lb. as it was delivered to the pulverizing mill. The water was weighed in two special test tanks placed on standard platform scales. The coal used on these tests was Pennsylvania coal from the Natrona mine.

United Rys. of Providence, R. I. The boiler tested, of the Bigelow-Hornsby type, had 12,660 sq. ft. of heating surface and is shown in Fig. 2. It was equipped with Foster superheater of 6060 sq. ft. of heating surface, and a Foster economizer of 7488 sq. ft. of heating surface.

The furnace was of hollow-wall construction with a steel casing. It was equipped with eight fantail Lopulco burners and a water screen over the bottom of the furnace having 320 sq. ft. of heating surface. The combustion space of the furnace was 9500 cu. ft. above the water screen. The distance between burner arch and the water screen was 26 ft.

The results of the tests are given in Tables 6 and 7. They were made by the test engineers of the United Railways of Providence in coöperation with those of Combustion Engineering Corporation. Coal was weighed in lots of 2000 lb. in a special hopper placed on standard platform scales. Water was measured in two special test tanks with conical bottom and top.

The coal used was New River coal and Rhode Island (Cranston Mine) coal, typical analyses of which are given in Table 9.

TABLE 9 TYPICAL PERCENTAGE COMPOSITIONS OF COALS USED IN TESTS

	Illinois	Kentucky	Penna. (Lucerne)	Pittsburgh	New River	Rhode Island[1]
Moisture............	12.91	2.00	3.00	1.51	2.52	9.71
Ash.................	11.64	9.94	11.40	11.85	8.00	25.71
Carbon..............	60.74	73.69	71.75	73.44	78.71	62.60
Hydrogen............	4.00	4.50	4.74	4.76	4.46	0.29
Nitrogen............	1.15	1.20	1.27	1.45	1.31	0.08
Sulphur.............	1.32	0.53	2.15	0.71	6.80	0.68
Oxygen..............	8.24	8.14	5.73	6.28	4.32	0.93
Volatile............	31.90	33.40	28.00	35.00	21.28	2.60
Fixed carbon........	43.55	54.50	57.60	51.60	68.20	61.98

[1] B.t.u. as received, 9700.

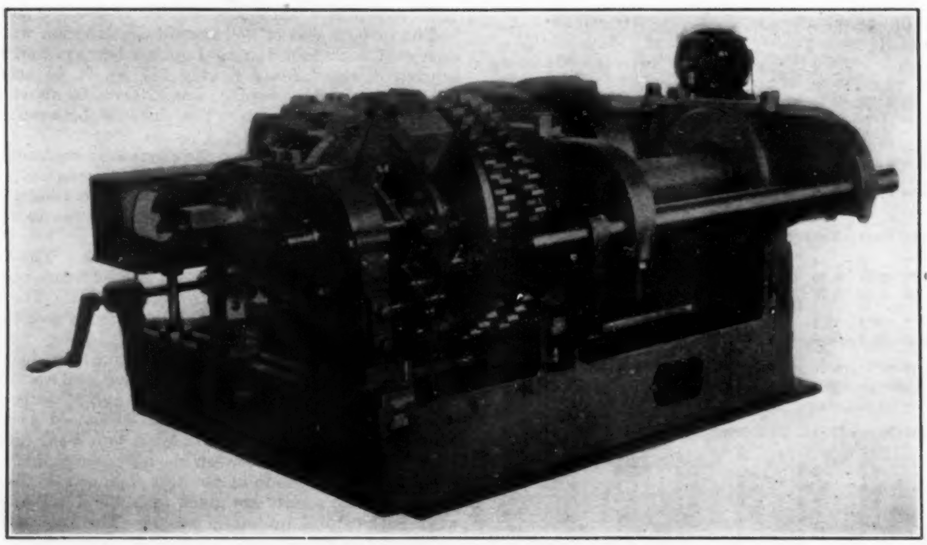
Gear-Testing Machine Designed for A.S.M.E. Research Work

THE gear-testing machine recently designed by Wilfred Lewis, one of the concrete results of the research activities of The American Society of Mechanical Engineers, was completed at the Bilgram Machine Works of Philadelphia, Pa., the last week of November, and was on exhibition on the first floor of the Engineering Societies Building during the recent Annual Meeting of the Society.

Recognizing the timely importance of a study of the effects of varying degrees of tooth accuracy and varying velocities on the strength of gear teeth, the Main Research Committee of The American Society of Mechanical Engineers, with the approval of the Council, organized a special research committee to make such a study. This committee held its first meeting in April, 1922, and requested Mr. Lewis to serve as chairman and to begin the systematic development of the design for a second gear-testing machine for which he had already made rough sketches. From time to time the members of the committee recommended modifications of the original drawings. They were then carefully examined by Prof. Charles E. Fuller, professor of theoretical and applied mechanics at the Massachusetts Institute of Technology, who made some suggestions and then heartily approved the design. At its April, 1924, meeting the committee finally approved the design and instructed the chairman to secure bids for the building of the machine.

The purpose of the machine is primarily to determine the effect of varying degrees of tooth accuracy and varying velocities on the strength of gear teeth.

The machine consists of a pair of test gears and pinions mounted in a swing frame centered in the axis of the pinion shaft and supported at a convenient distance upon weighing scales. By this means the torque can be measured when transmitting power received from a belt on a flywheel pulley mounted on the pinion shaft. The test gears are mounted on a telescopic sleeve and shaft, in which an initial torque can be introduced through a connecting nut of long pitch at the outer end of the telescope. The elastic reaction of the telescope maintains any desired average load on the gear teeth, which is augmented and reduced in action by the inaccuracies in the teeth and by the speed. Insulated ball bearings are used throughout, and electric circuits are established through telephone receivers which may be interrupted when either test gear fails to make contact with its pinion. When starting and at slow speeds, there will be no interruption, but as the speed is increased there will come a time when the inaccuracies cause a momentary break in tooth contact. This will be announced by one of the telephone receivers and at that moment the corresponding speed, as indicated by the tachometer, is noted. Another initial load will show a different breaking speed, and in this way the loads and speeds can be correlated by experiment. For rigid teeth in rolling contact, the initial load required to maintain contact is proportional to the speed squared, and the departure from this relation may be ascribed to elasticity and mass effects. For the accurate determination of the latter, special provision has been made in the application of a torsion balance to the pinion shaft direct. A light rod of tempered steel is attached to the pinion shaft and anchored at its outer end. A capillary pen mounted in a holder traversed by the oscillation of the pinion shaft moves over a paper ribbon traveling at a known rate of speed. This device makes possible the accurate determination of the oscillating period for the pinion shaft alone with and without one or two of the flywheels, and with or without each of the test gears.



Gear-Testing Machine

Provision has also been made to multiply and record the inaccuracies in the teeth on circular diagrams in which they will appear as radial displacements, and a novel feature of this mechanism is that diagrams can be made and compared for the same teeth under very heavy loads as well as under the ordinary comparatively light loads which cannot show the effects of elastic deflection and compression.

Care has been taken to make the recording mechanism very sensitive and accurate, and it is believed that the data obtained in this way will add very much to a clearer understanding of the effect of speed upon the strength of gear teeth and of many other problems in efficiency, wear, and noise.

From New York the machine will be shipped direct to the Massachusetts Institute of Technology, where the first series of tests will be made under the direction of Prof. E. F. Miller, head of the department of mechanical engineering. Dr. S. W. Stratton, president of the Institute, has expressed keen interest in the work of the committee and has offered to provide the necessary observers and mechanical power without cost to the committee.

The following tentative program has been worked out:

Test 1. The pair of test gears are to be duplicates of the back gears,[1] that is, with accurately ground teeth.

Test 2. The pair of test gears are to have an error of 0.0005 in. in spacing of teeth only.

Test 3. The pair of test gears are to have a spacing error of 0.002 in.

Test 4. The pair of test gears are to have a predetermined error in normal pitch of 0.0005 in. and of 0.0020 in., respectively, the normal pitch of the driver being increased.

Test 5. Conditions of Test 4 reversed, i.e., the pair of test gears to have an error in normal pitch of 0.0005 in. and 0.0020 in., the increase being in the driven gear or follower.

[1] The back gears or pinions to be ground as perfect as is possible in all tests made. These gears to be fixtures.

Test of Pulverized-Fuel-Fired Boilers at the Lake Shore Station, Cleveland

By JOHN WOLFF,[1] CLEVELAND, OHIO

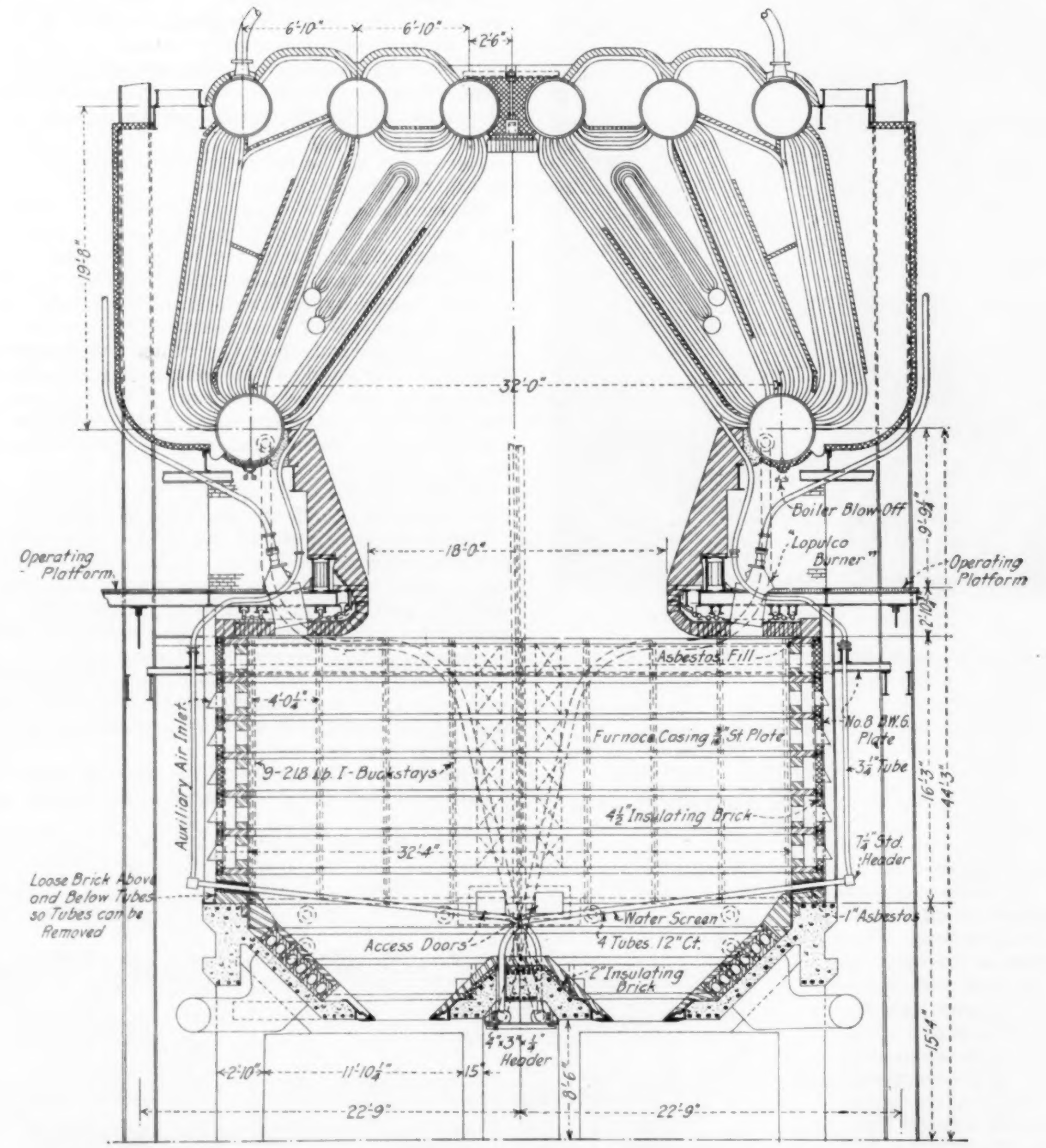


Fig. 1 Cross-Section of Boiler and Furnace Equipped for Burning Pulverized Coal, Lake Shore Station, Cleveland

The pulverized-coal-burning equipment of the Lake Shore Station of the Cleveland Electric Illuminating Company was described by Mr. W. H. Aldrich in a paper[2] presented at the Spring Meeting of the Society last May. Since that time complete tests have been run, the objects of which were to compare the results with guarantees and to determine the general economy and detailed characteristics of the installation.

[1] Mechanical Engineer, Cleveland Electric Illuminating Company. Mem. A.S.M.E.

[2] Pulverized Fuel at the Cleveland Illuminating Company's Lake Shore Plant. Published in Mechanical Engineering, September, 1924, p. 519.

To be presented at a joint meeting of the Cleveland Engineering Society and the Cleveland Sections of the American Society of Heating and Ventilating Engineers and The American Society of Mechanical Engineers, Cleveland, Ohio, January 13, 1925. Contributed by the Cleveland Section of the A.S.M.E.

Fig. 1 shows a cross-section of the boiler and furnace and Fig. 3 a cross-section through the boiler room and preparation plant. A summary of the equipment is given below.

Boilers, Duplex Stirling	30,600 sq. ft.
Superheaters, B. & W.	4,520 sq. ft.
Water screen	835 sq. ft.
Economizers, Power Specialty Company	22,080 sq. ft.
Furnace volume, above screen	26,000 cu. ft.

Driers: None used. Provision is made for waste-heat driers if necessary
Mills: Raymond, 6-roll, 6 tons per hour
Secondary Air Dampers: Bailey Meter Co., 24 per unit
Burners: Lopulco, 16 per unit
Feeders: Lopulco, 16 per unit
Feeder Drive: Individual d.c. motors, 1.5 hp. each
Blowers: Primary air, No. $4^1/_2$ Sturtevant
Conveyors: Screw type, 14 in. diam.

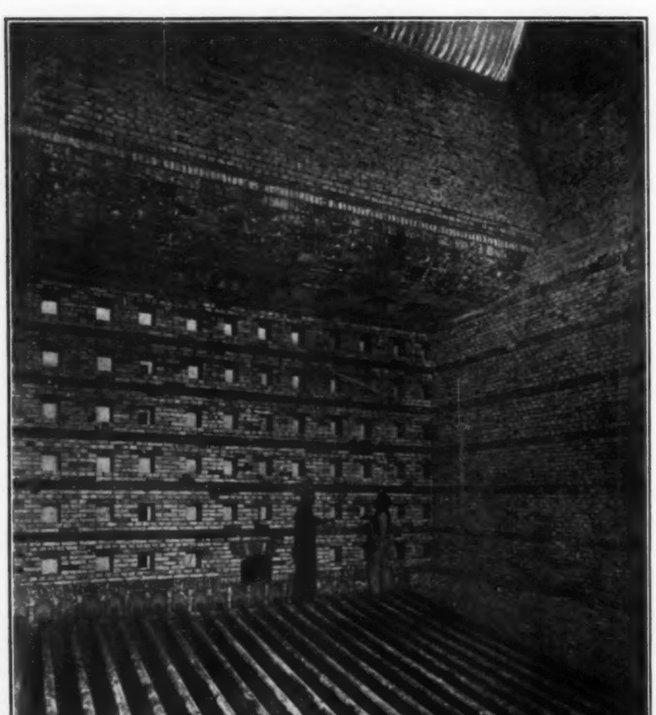


FIG. 2 INTERIOR VIEW OF FURNACE

Induced-Draft Fans; No. 10 Sturtevant Cindervane.
Motors (G. E. Co.):

Voltage	Current	Hp.	R.p.m.	To drive
220	d.c.	1.5	500–1500	feeders
2200	a.c.	100	1200	blowers
440	a.c.	15	900	conveyors
2200	a.c.	100	450	mills
2200	a.c.	50	1200	mill exhausters
2200	a.c.	150	120–360	induced draft

The feature of this installation by which changes in coal are automatically compensated for is the control system. This is best described as consisting of two separate controls: first, an individual control for each boiler by means of which the excess air for combustion is automatically maintained at a predetermined amount according to the boiler rating; and second, a master control by means of which the output of all the boilers is governed according to the steam pressure.

The individual boiler control is based on the total air flowing through each boiler, and each boiler control is now set to maintain the CO_2 as shown in Fig. 4. By this means the furnace temperature is kept approximately constant, irrespective of rating. In the actual operation of this control the induced-draft fans are speeded up or slowed down according to whether the excess air is too low or too high for that rating. If the rating is below the point at which the fans are used, the adjustment is made by means of a damper on the fan uptake.

The master control is operated by the station steam pressure. When the pressure drops below standard an impulse is given to all the boilers which increases both the coal feed and air supply, and the opposite occurs for an increase in pressure. For changes in rating the air supply is always increased faster and decreased slower than the coal supply in order that there shall always be an excess of air during a change in rating. For a small drop in steam pressure the boilers receive intermittent impulses of short duration until the pressure comes back to normal. If the pressure drops further instead of coming back to normal, the intermittent impulses become of longer duration according to the amount of pressure drop. The duration of the intermittent impulse depends on the amount of the pressure drop.

This system has proved entirely satisfactory and is not subject to bad "hunting."

The method of conducting the tests was as follows: Both coal and water were weighed by balance scales which were checked by standard weights before and during the tests. Necessary precautions were taken to make certain that there was no possibility of water leakage by the installation of blanks and "telltales," and routine inspections of these were made every two hours. The coal was weighed and sampled as it entered the powdered-coal bins. Except for a few shutdowns the boiler was under continuous testing. The finish of one test was the start of the next test. Each test was approximately 24 hours long. At the conclusion of each test the coal in the powdered-coal bins was leveled off at about three feet above the feeders.

All thermometers were calibrated before the tests, and the more important ones at different times during the tests.

Due to the great width of the boiler, CO_2 samples were taken at five points across each boiler uptake. Each point was sampled separately in rotation from a collecting bottle which had been filling while the previous sample was being analyzed. Two Orsats were used for the boiler gas samples. CO_2 samples were taken in a similar manner at three points across the uptake of each economizer. Before the tests were started velocity traverses at different ratings were taken in the boiler uptake and the economizer outlet in order that the gas samples and temperatures should represent the weighted average as near as possible.

With the exception of two of the tests the firing was manual. The CO_2 for each rating was carried at the highest point possible

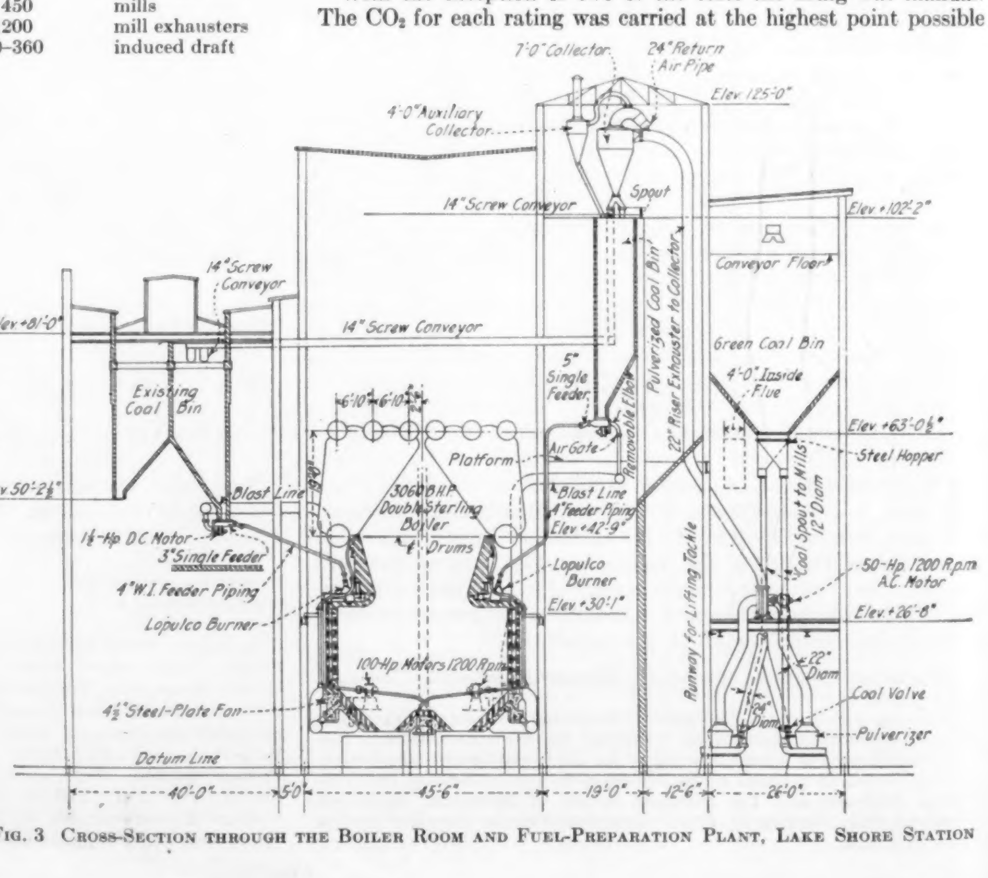


FIG. 3 CROSS-SECTION THROUGH THE BOILER ROOM AND FUEL-PREPARATION PLANT, LAKE SHORE STATION

TABLE 1 DATA OF PULVERIZED-FUEL-BURNING TESTS OF NO. 87 BOILER, MAY-JULY, 1924

																	Starting Tests		Banking Tests				Bailey Control Tests	
Test No.	13A	13	4	14	2	5	15	21	6	16	9	20	7	17	8	19	12	18	22	22A	3	10–11	23A	23
Duration, hours	22.92	21.60	26.45	23.68	22.03	18.75	25.08	24.17	24.53	21.78	18.67	22.82	23.93	26.43	30.27	24.98	36.28[1]	25.82[1]	26.90[1]	24.68[1]	28.05[1]	47.95[1]	28.17	20.28
Rating, per cent	51	54	94	103	140	143	152	165	182	204	214	220	228	233	242	270	87	142	105	108	133	141	122	134
Coal as Fired																								
Through 50 mesh, per cent	98.6	98.8	95.9	98.4	94.9	96.4	98.9	97.5	98.2	99.2	97.8	96.9	98.8	99.3	97.7	98.3	98.8	98.2	98.9	98.8	97.8	98.9	98.8	98.8
Through 100 mesh, per cent	91.1	92.5	88.3	91.3	86.8	86.5	91.2	88.6	90.4	92.6	91.4	86.8	91.9	93.8	90.1	91.6	92.0	90.1	90.9	90.2	90.2	90.8	90.1	90.8
Through 150 mesh, per cent	81.5	81.4	79.9	82.5	78.2	82.9	81.9	79.2	84.0	83.8	84.7	76.9	85.5	86.2	83.3	82.2	82.5	81.2	81.7	80.9	85.0	80.6	80.5	81.7
Through 200 mesh, per cent	72.9	69.9	75.6	73.6	72.6	79.2	72.5	70.4	79.5	74.9	77.8	67.9	77.9	79.6	75.5	74.4	72.4	72.6	72.9	72.1	79.9	70.8	71.1	73.0
Moisture, per cent	2.6	2.5	2.7	2.1	2.6	3.0	2.3	2.0	3.4	2.0	1.7	2.3	2.2	1.7	2.4	2.0	2.2	1.7	2.4	2.3	2.6	1.9	2.5	1.7
Ash, per cent	10.7	10.7	12.2	11.1	12.2	11.1	10.5	10.4	11.7	10.7	12.6	10.4	13.1	10.6	12.8	10.7	11.1	10.9	10.5	10.5	11.9	11.8	10.3	10.4
B.t.u. per lb.	12,590	12,609	12,400	12,578	12,545	12,629	12,686	12,696	12,491	12,781	12,473	12,691	12,283	12,765	12,371	12,717	12,619	12,694	12,587	12,684	12,399	12,543	12,684	12,738
Fired per hr., lb.	5,244	5,351	9,317	10,360	13,561	14,092	14,951	16,374	18,479	20,431	21,757	21,930	23,702	23,253	25,205	27,445	9,785	15,608	10,154	10,874	13,341	14,170	12,160	13,512
Per cu. ft. combustion space per hr., lb.	0.20	0.21	0.36	0.40	0.52	0.54	0.58	0.63	0.71	0.79	0.84	0.84	0.89	0.89	0.97	1.06	0.38	0.60	0.39	0.42	0.51	0.55	0.47	0.52
Water, Lb.																								
Evaporated per hr	47,582	50,584	87,956	94,523	131,438	132,257	139,847	153,177	167,959	187,540	198,591	205,677	210,921	218,991	225,578	254,357	81,804	135,175	97,420	100,371	126,224	132,127	113,596	124,123
Evaporated per lb. coal	9.07	9.45	9.44	9.12	9.69	9.39	9.35	9.35	9.09	9.18	9.13	9.38	8.90	9.42	8.95	9.27	8.36	8.66	9.59	9.23	9.46	9.32	9.34	9.19
B.t.u. per lb. steam	1299	1300	1307	1332	1328	1342	1356	1341	1357	1366	1356	1349	1366	1350	1362	1353	1310	1333	1320	1323	1322	1328	1345	1348
Temperatures, Deg. Fahr.																								
Air to furnace	99	96	85	91	72	77	85	84	70	82	80	81	73	88	85	77	88	86	101	96	73	91	84	81
Air to feeders	97	96	91	99	92	91	105	104	89	104	93	101	93	111	99	100	96	107	109	100	93	92	100	101
Gases leaving boiler	409	425	457	467	509	519	530	529	564	587	596	595	621	620	631	646	469	524	468	481	502	507	517	532
Gases leaving economizer	169	174	203	203	229	230	235	234	252	263	259	274	274	296	281	318	204	242	213	209	218	229	231	237
Water to economizer	125	123	143	137	157	147	151	142	143	152	144	152	147	150	146	153	141	150	140	133	157	143	144	136
Water to boiler	205	215	219	218	242	238	242	236	247	255	255	256	259	264	265	265	221	256	221	219	242	239	243	243
Superheated steam	571	573	587	638	630	656	686	656	687	706	686	672	706	675	698	681	593	640	613	622	615	628	664	670
Pressure, Lb. per Sq. In. Abs.																								
Boiler	253	253	251	255	254	254	257	259	256	262	256	264	259	264	260	270	254	259	255	254	253	252	256	256
Superheater	251	251	250	252	253	252	254	257	254	258	254	261	257	259	257	265	252	255	254	253	251	252	255	255
Drafts, Inches of Water																								
Furnace	0.18	0.22	0.23	0.29	0.20	0.25	0.35	0.34	0.36	0.47	0.35	0.45	0.39	0.54	0.38	0.58	0.24	0.37	0.28	0.28	0.20	0.26	0.30	0.30
Leaving boiler	0.06	0.02	0.06	0.10	0.22	0.27	0.33	0.33	0.55	0.78	0.77	0.91	0.94	1.45	1.21	1.54	0.07	0.50	0.09	0.10	0.24	0.24	0.26	0.34
Leaving economizer	0.06	0.17	0.57	0.34	0.82	0.99	1.16	1.12	1.98	2.56	2.68	3.01	3.18	4.39	4.08	5.15	0.28	1.63	0.41	0.45	0.82	0,76	0.91	1.17
Air to feeders, pressure	6.4	6.1	8.8	6.9	6.5	8.2	8.4	8.8	9.8	10.2	9.3	9.1	10.2	9.8	10.3	9.9	6.3	8.7	8.2	9.7	7.6	8.8	8.2	8.4
Percentage Analysis of Gases																								
CO_2 leaving boiler	13.0	12.0	15.2	15.3	14.8	14.6	15.0	15.1	14.5	14.7	14.5	14.4	14.5	13.8	14.3	14.2	14.9	12.3	15.5	15.4	15.1	14.5	13.3	13.7
O_2 leaving boiler	5.8	7.1	3.1	3.5	3.6	3.9	3.5	3.5	4.0	3.7	4.0	4.3	3.9	4.7	4.3	4.3	3.8	6.4	3.2	3.0	3.4	3.9	5.6	5.3
CO leaving boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO_2 leaving economizer	13.0	12.0	15.1	15.0	14.7	14.3	14.5	14.6	14.1	13.8	14.2	14.2	14.0	13.3	13.8	14.0	15.0	12.3	14.8	15.1	14.4	14.1	12.7	13.2
O_2 leaving economizer	5.8	6.9	3.3	3.4	3.7	4.2	3.8	3.6	4.5	4.7	4.6	4.5	4.4	5.2	4.9	4.7	3.3	6.6	2.9	3.3	3.5	4.3	5.5	5.0
CO leaving economizer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat Account in Per Cent																								
Heat absorbed by boiler and superheater	81.1	83.7	85.3	83.1	86.4	84.4	84.5	83.7	83.0	82.0	82.9	83.1	82.5	82.5	81.6	81.5	74.3	75.6	86.2	82.8	84.6	83.3	83.4	81.9
Do., boiler, superheater and economizer	86.9	90.6	91.0	89.0	92.9	91.2	91.2	90.7	90.7	89.5	91.1	90.8	90.6	90.9	90.3	89.8	79.6	82.9	92.3	89.0	91.2	90.4	90.8	89.7
Loss in dry gases	1.8	2.1	2.6	2.5	3.6	3.5	3.5	3.5	4.2	4.4	4.2	4.5	4.8	5.2	4.7	5.8	2.6	4.2	2.5	2.5	3.4	3.2	3.9	3.9
Loss in water vapor	3.6	3.6	4.1	4.0	3.8	4.0	4.1	3.7	4.3	4.1	4.0	3.9	4.1	4.2	4.2	3.6	4.0	4.0	4.0	4.0	4.2	4.0	4.2	3.9
Loss in radiation, combustible ash, and unaccounted for	7.7	3.7	2.3	4.5	−0.3	1.3	1.2	2.1	0.8	2.0	0.7	0.8	0.5	—0.3	0.8	0.8	13.8	8.9	1.2	4.5	1.2	2.4	1.1	2.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
[1] Duration of banking, hours	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	10.28	3.55	5.17	5.12	11.47	9.60	......	......

without damage to the furnace walls. This resulted in the curve shown in Fig. 5. Since the tests, improvements in the end-burner operation and air distribution have been made which make it possible to carry slightly higher CO_2 than shown in Fig. 4.

Two tests, using automatic control, were run with the boiler operating under plant load conditions, during which periods the boiler rating varied from 90 to 240 per cent, the resultant efficiencies conforming very closely to test results based on a weighted average for the ratings in question.

The results of these tests should also be considered as the results of actual operation since the test results are automatically maintained in every-day operation irrespective of changes in coal.

Plant records show the following monthly efficiencies for this installation.

	Efficiency, Gross	Per Cent Net
July	87.8	85.9
August	90.1	88.2
September	90.4	88.3
October	88.4	86.8
November	90.0	88.2

The coal weights for the above are taken from track scales and the coal sample is taken just after the coal is crushed. According to recent tests the track scales show 0.50 to 1.00 per cent more coal (on a dry basis) than the pulverized-coal scales used on the test. Most of this difference is due to moisture lost in process of pulverization, but the monthly efficiencies shown above are not corrected for this amount. The net efficiency is calculated from the total energy used in coal preparation (exclusive of crushing, i.e., reduction in size from mine run to slack), conveyors, feeders, and forced- and induced-draft fans. In other words, the coal equivalent for the above operation is charged against the boiler.

No special coal was used for these tests, the supply being the regular plant supply from several different shippers and some market coal. A sample analysis on the as-fired basis is as follows:

Proximate Analysis

B.t.u.	12,629
Moisture, per cent	2.3
Volatile, per cent	35.4
Fixed carbon, per cent	51.2
Ash, per cent	11.1
	100.0

Ultimate Analysis

Moisture, per cent	2.3
Carbon, per cent	68.9
Hydrogen, per cent	4.8
Nitrogen, per cent	1.1
Oxygen, per cent	8.1
Ash, per cent	11.1
Sulphur, per cent	3.7
	100.0

The fusion temperature of the ash of the coal used as compared with that of the brick is shown below. In actual

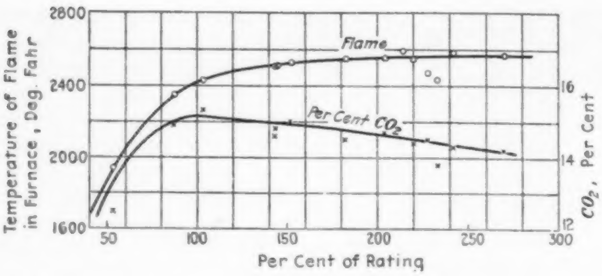


FIG. 4 FURNACE FLAME TEMPERATURES AND CO_2 CONTENTS AT VARIOUS RATINGS

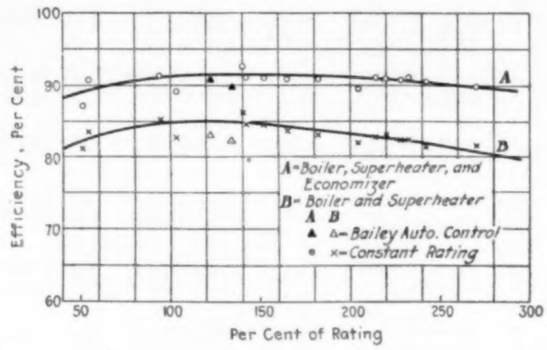


FIG. 5 EFFICIENCIES AT VARIOUS RATINGS, CONSTANT RATING AND AUTOMATIC CONTROL

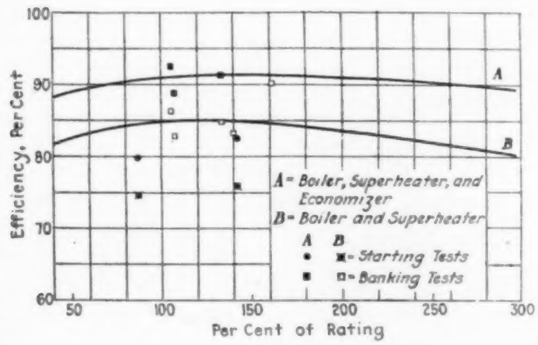


FIG. 6 EFFICIENCIES AT VARIOUS RATINGS, STARTING AND BANKING TESTS

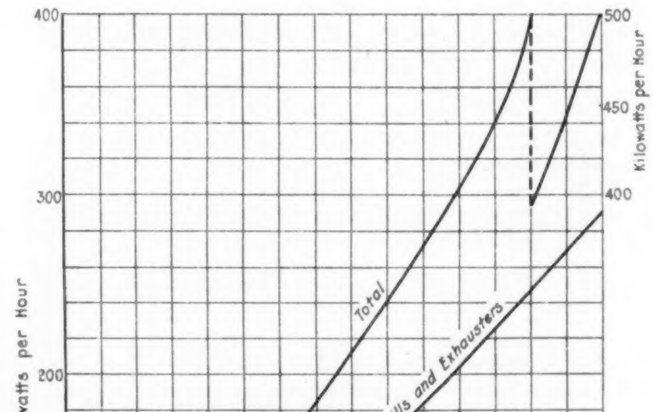


FIG. 7 PREPARATION ENERGY, KILOWATTS PER HOUR AT GENERATOR

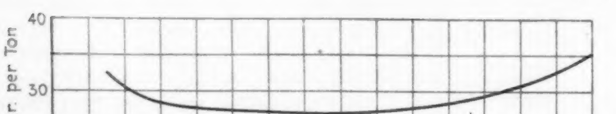


FIG. 8 PREPARATION ENERGY, KILOWATT-HOURS AT GENERATOR PER TON

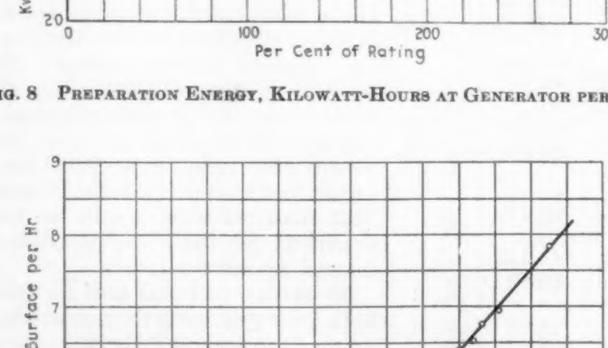


FIG. 9 B.T.U. ABSORBED PER SQ. FT. OF BOILER HEATING SURFACE PER HOUR

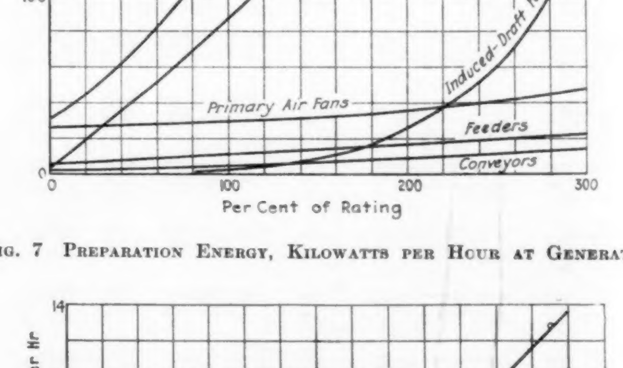


FIG. 10 B.T.U. PER CU. FT. OF EFFECTIVE FURNACE VOLUME PER HOUR

operation the flame has to be kept away from the furnace wall, for the brick is eroded at temperatures above the fusion temperature of the coal ash.

	Softening point, deg. fahr.	Melting point, deg. fahr.
Plaster coating	2598	2640
Brick	2585	2650
Coal ash	2016	2147

In order to determine the schedule of operation of these boilers in connection with the rest of the plant, several banking tests and two starting tests were run. Fig. 6 shows that for a 5–10-hour bank there is no appreciable loss in efficiency. To bring one boiler unit from room temperature to that corresponding to 100 or 150 per cent of rating, considerable heat is absorbed by the structure which is not used in generating steam. As calculated from the drop in efficiency of these starting tests below the curve (Fig. 6), about 26 tons of coal are lost in bringing one of these boilers from room temperature up to the temperature corresponding to 100–150 per cent rating.

Temperatures and miscellaneous firing data are shown in Table 1.

Before the tests were started, the equipment was given a complete inspection. The economizer appeared clean, but the draft loss subsequently showed that there must be considerable deposit on the tubes. The economizer was cleaned after the tests and Table 2 shows the draft loss after cleaning. The draft loss shown in Table 2 is therefore not representative. Detailed tests were also run before and after cleaning to determine the change in heat transfer. These tests showed that the deposit on the outside of the tubes was of such nature as to affect materially the draft loss and only slightly the heat transfer.

TABLE 2 DRAFT LOSS AT VARIOUS RATINGS

Per cent rating	Draft loss, inches of water
100	0.09
125	0.18
150	0.30
175	0.45
200	0.60
225	0.75
250	1.05
275	1.40
300	1.90

Figs. 7 and 8 show the preparation energy per ton and also for different boiler ratings.

The Effect of Inaccuracy of Spacing on the Strength of Gear Teeth

By LLOYD J. FRANKLIN[1] AND CHARLES H. SMITH[2]

In a paper presented before the Society in 1912, Professor Guido H. Marx reported results of an extended series of tests to determine the strength of gear teeth at pitch velocities from 0 to 500 ft. per min. During the discussion of this paper it was suggested that further tests be made in order to obtain definite data as to the effect of inaccuracy of spacing on the strength of the teeth at high speeds. At the instance of Professor Marx the authors undertook such a series of tests, the results obtained and a description of the apparatus and procedure employed being given in the present paper.

Among other things the authors found that, in a broad way, at pitch velocities of 1000 ft. per min. and upward, gears whose inaccuracies of spacing do not exceed 0.001 in. will carry twice the load that those having inaccuracies of spacing of 0.006 in. will; and that the strength of gears having inaccuracies of spacing of the order of 0.002 in. is about half-way between the two. An error of 0.006 in. in the size of teeth tested is much more than will ordinarily be found in first-class commercial cut gears.

PREVIOUS to the year 1911 there had been very little experimental investigation of the strength of gear teeth—at least if such tests were made there are no records of them available. During 1911 and 1912, Prof. Guido H. Marx of Stanford University, Cal., performed quite extensive tests dealing with the strength of gear teeth. The report of these tests[3] shows the results obtained by him in testing gears for the strength of the teeth at pitch-circle velocities from 0 to 500 ft. per min. These tests were supplemented[4] by Professor Marx assisted by Prof. L. E. Cutter in 1914, at which time they conducted tests to determine the strength of gear teeth at pitch velocities as high as 2000 ft. per min.

In the discussion following the first of these papers, R. E. Flanders says: "It is also important to know how much the accuracy of the cutting affects the strength of the gears at high speed. All grades of accuracy are used in commercial work. To investigate this matter it might be possible to try two or three sets of gears; one made with the cutter set central, the next with the cutter off center 0.002 in. and the others with the cutter set off center 0.003 or 0.004 in. The chances are that an investigation of this kind would show that a high premium is put on accuracy of cutting from the standpoint of strength. If this is so it should be definitely known, though it is not practicable to include the factor in a formula."

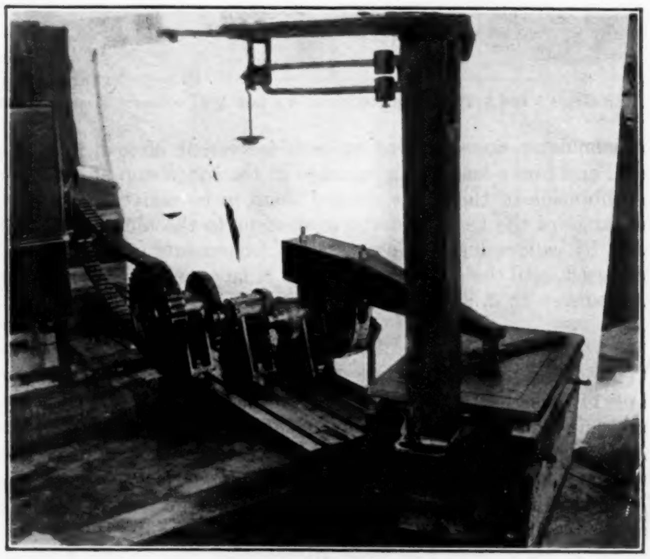


FIG. 1 GEAR-TESTING APPARATUS

At the suggestion of Professor Marx the authors decided to undertake a series of tests which would, it was hoped, give some definite data as to the effect of inaccuracy of spacing on the strength of gear teeth. Accordingly, the apparatus used by Professors Marx and Cutter in 1914 was restored to working order and set up as shown in Fig. 1.

DESCRIPTION OF THE APPARATUS

The motor, a 50-hp., three-phase, induction type, capable of carrying a heavy overload momentarily, was connected by a Morse silent chain to a shaft on which were mounted a large sprocket

[1] Draftsman, San Bernardino Ice and Precooling Plant, San Bernardino, Cal. Jun. A.S.M.E.

[2] Instructor in Mechanical Engineering, Stanford University, Cal. Jun. A.S.M.E.

[3] Trans. A.S.M.E., vol. 34, 1912, p. 1323.

[4] Trans. A.S.M.E., vol. 37, 1915, p. 503.

Contributed by Machine Shop Practice Division and presented at the Annual Meeting, New York, December 1 to 4, 1924, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

and one of a pair of steel change gears on opposite sides of a pedestal bearing. The second of these two 8-pitch steel change gears was keyed to an intermediate shaft on which was also mounted the driving gear of the test pair. The remaining shaft, mounted in a similar manner, held the driven test gear and the brake wheel. The brake used was the same design as shown by Professors Marx and Cutter in the report of their tests. A platform scale supported the brake arm by means of a plate and knife edge, the latter being mounted on the arm. This arrangement is shown clearly in Fig. 1. When the apparatus was in operation, guards, not shown in Fig. 1, were placed over the gears. The change gears were lubricated by dipping in a bath of heavy steam-cylinder oil, and the chain and test gears were lubricated by a mixture of graphite, grease, and oil applied at the start of each run.

Test Procedure

The tests were all made in the laboratory at Leland Stanford Junior University. For each run the motor was started at zero load and the brake gradually tightened until the gears ruptured. Upon conclusion of the tests an effort was made to determine whether individual tooth errors as shown by the diagrams were responsible for rupture of the gears. It was shown clearly by marking several of these charts that this could not be depended upon, for at times what appeared as a good portion of the gear on the chart would be stripped, and vice versa. This may have been due to slightly dirty gears when the charts were made, or to improper manipulation of the machine. On the marked charts the letter *S* means tooth sheared; *B*, broken out; *P*, partially broken; and *C*, cracked. Notation outside of the diagram is for the driver, notation inside the diagram for the driven gear.

Description of the Tests Performed

The tests were conducted in three series. The first series was made at a pitch-line velocity of approximately 1000 ft. per min.; the second at about 1500 ft. per min.; and the third close to 2000 ft. per min. Three runs were made with each type of gear in each series in order that a check might be made with the conditions of loading and testing as closely identical as possible. The gears were set up accurately so that the correct teeth as shown by the Saurer diagrams were in mesh with one another, and the adjustments for fit, alignment, and backlash were made very carefully in all cases.

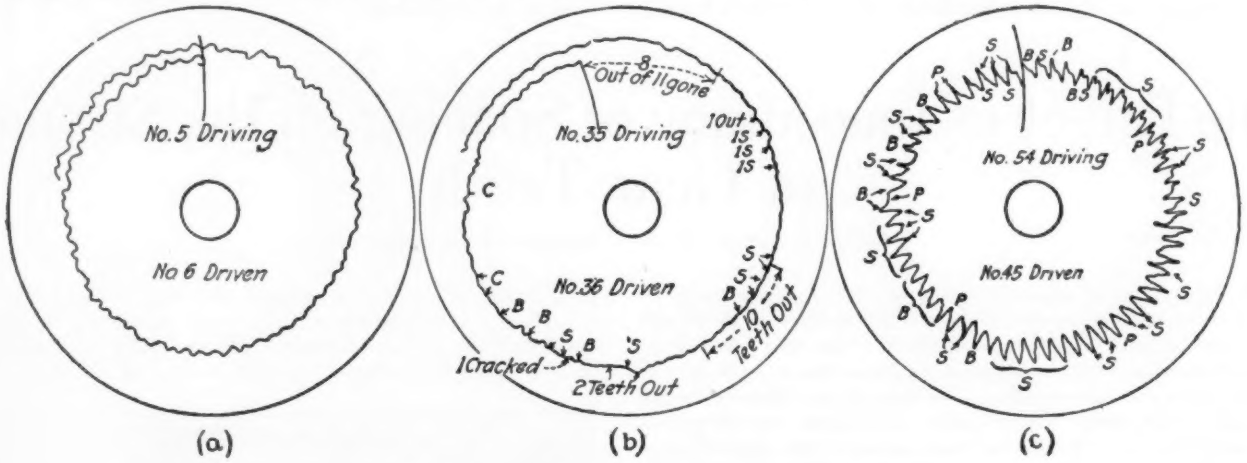


Fig. 2 Saurer Gear Charts (Reduced in Size)
(*a* Gears 5 and 6, B. & S. milled, used in a test A 3; *b* Gears 35 and 36, Maag used in test C 10 and 11; *c* Gears 54 and 45, "Mismated," used in test C 7.)

A tachometer was observed at each increment of load, the final speed and brake load being recorded at the conclusion of each test. A calibration of the scales showed them to be correct throughout the range of the tests, and the corrections to the tachometer were made by calibrating the instrument. Increments of load of 5 lb. were used until the gears showed signs of labor, when the increment was reduced to 2, and finally to 1 lb.

Types of Gears Tested

The gears tested were all 10-diametral-pitch, 60-tooth, cast-iron, $14^1/_2$-degree involute type furnished by Pratt & Whitney Company especially for the tests. The width of face of the gears was $1^1/_{16}$ in. and the bore $1^5/_{16}$ in. A $^5/_{16}$-in. key was used to secure the gear to the shaft. Extra long hubs ($1^1/_2$ in.) were used on all the gears, as it was found by an examination of the test which was previously made by Professors Marx and Cutter that several of their tests had been disregarded due to the keyways failing.

The gears were divided into three classes according to the accuracy of the spacing. In one class where the ordinary milled gears were cut with a Brown & Sharpe milling cutter; another class was composed of what were called "standard Maag gears;" and the third class was made up of a series of "mismated" gears purposely constructed with inaccuracy of spacing. The error of the spacing of these three classes is about as follows:

Maag gears, from 0.0005 to 0.001 in.
Ordinary milled gears, ± 0.002 in.
Mismated milled gears, ± 0.006 in.

These errors may be seen on the Saurer gear charts that were furnished with the gears. In the charts a departure of 0.030 in. from a perfect circle represents an error of approximately 0.001 in. Three of the actual charts are shown on a reduced scale in Fig. 2.

Static tests of the gears were made with the teeth in the weakest position as shown in Fig. 3, in order that experimentally complete curves might be drawn. These tests were made by using a single-toothed steel gear in mesh with the cast gears. Care was taken in testing to see that the load came on the tooth at the point shown, but due to the spring in the apparatus there is some doubt as to the accuracy of some of the results. This spring was noticed by Professors Marx and Cutter in their tests.[1] It is fairly safe to assume a value of 3200 lb. as the breaking load for the ordinary and "mismated" milled gears. The Maag gears showed a noticeably higher breaking strength in the static tests, the average being 3300 lb.

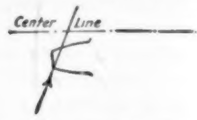


Fig. 3 Diagram Showing Method of Making Static Test

At the conclusion of the tests of the gear teeth, test specimens $^1/_4$ by $1^1/_{16}$ by 4 in. were cut from all gears in order that a check on the material might be made. For the purpose of comparison all values of breaking loads were reduced to correspond to a flexural strength of 56,320 lb. per sq. in.—found as the average strength of all specimens tested.

In order to determine definitely the material and structure of the metal used in the various types of gears, samples of each type were analyzed in the University metallurgy laboratory by Mr. Samuel E. Vaughan, a graduate student interested in materials. The chemical analyses and photomicrographs of the gears included in his report, show that the metal (really semi-steel) in the different types of gears tested is as uniform as could be expected for cast iron, both as to structure and chemical constituents. All six

[1] *Loc. cit.*, Appendix No. 1, notes.

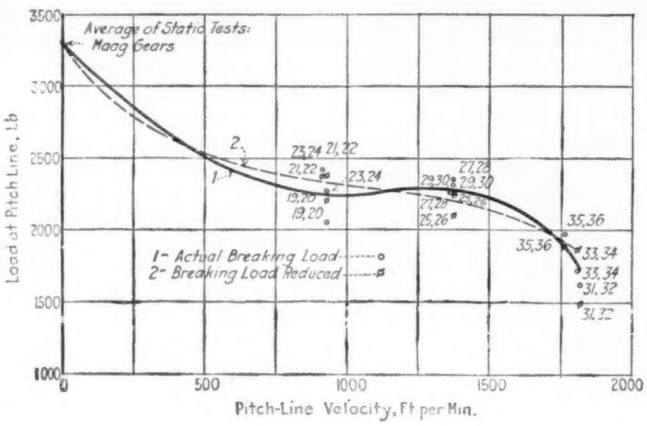


FIG. 4 CURVES FOR MAAG GEARS, SHOWING RELATION TO PITCH-LINE VELOCITY OF ACTUAL BREAKING LOAD (1) AND BREAKING LOAD REDUCED TO UNIFORM MODULUS OF 56,300 LB. PER SQ. IN. (2)

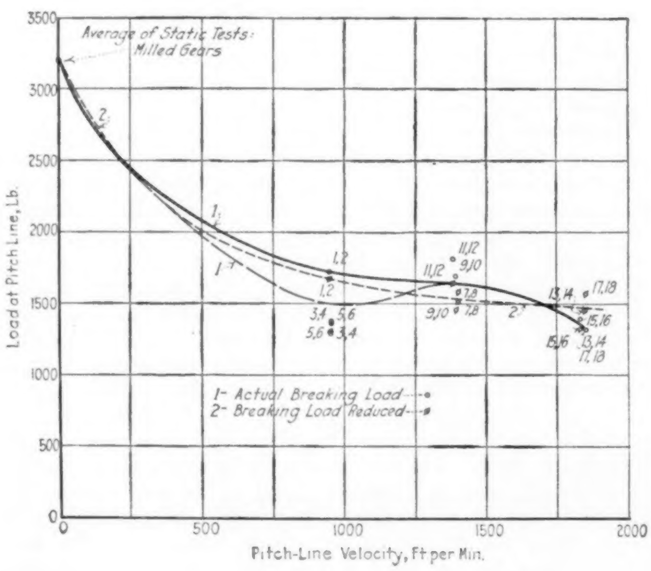


FIG. 5 CURVES FOR B. & S. MILLED GEARS, SHOWING RELATION TO PITCH-LINE VELOCITY OF ACTUAL BREAKING LOAD (1) AND BREAKING LOAD REDUCED TO UNIFORM MODULUS OF 56,300 LB. PER. SQ. IN. (2)

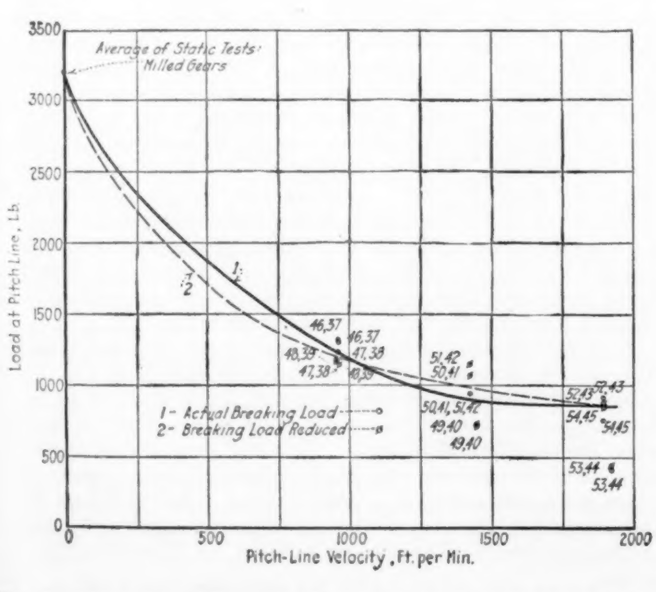


FIG. 6 CURVES FOR MISMATED GEARS, SHOWING RELATION TO PITCH-LINE VELOCITY OF ACTUAL BREAKING LOAD (1) AND BREAKING LOAD REDUCED TO UNIFORM MODULUS OF 56,300 LB. PER SQ. IN. (2)

specimens showed a uniform Brinell hardness number of 229. A 10-mm. ball was used with a load of 3000 kg. The chemical analyses are as follows:

Specimen No.	10	17	29	30	45	49
Total carbon	3.05	3.20	2.99	3.00	3.03	2.98
Graphitic carbon	2.21	2.26	2.32	2.31	2.22	2.17
Combined carbon	0.84	0.94	0.67	0.69	0.81	0.71
Silicon	1.77	1.65	1.84	1.75	1.78	1.64
Manganese	0.41	0.49	0.48	0.51	0.43	0.44
Sulphur	0.112	0.118	0.110	0.103	0.118	0.096
Phosphorus	0.502	0.491	0.552	0.478	0.536	0.517

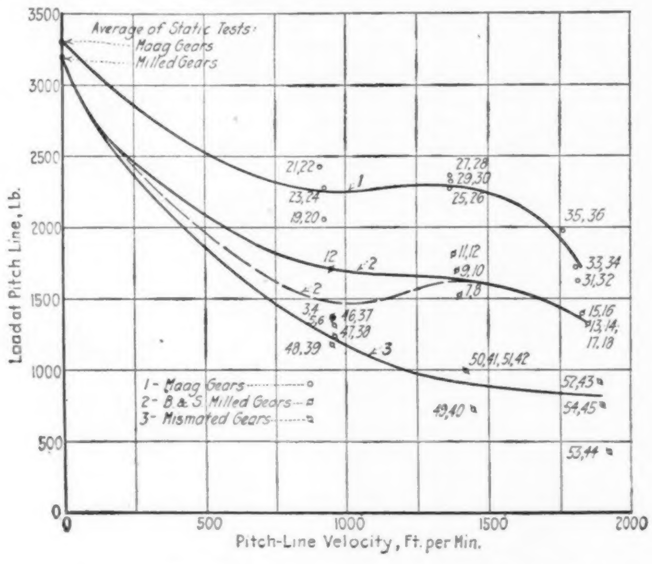


FIG. 7 CURVES SHOWING RELATION OF ACTUAL BREAKING LOAD TO PITCH-LINE VELOCITY

((1) Maag gears, (2) B. & S. milled gears, (3) Mismated gears.)

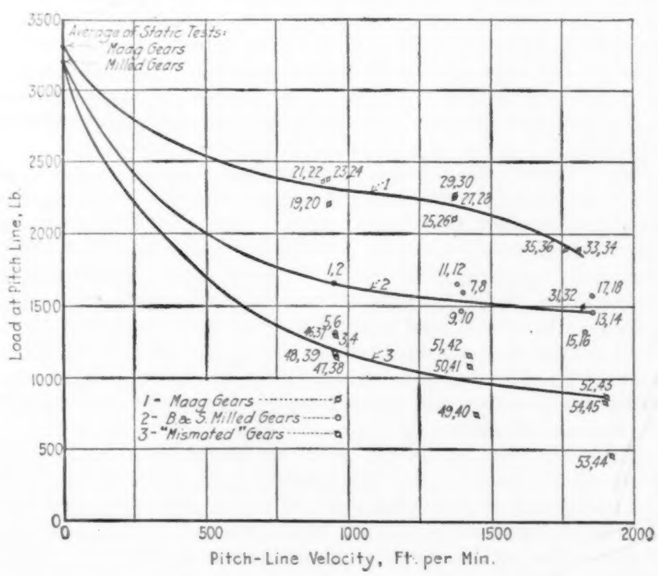


FIG. 8 CURVES SHOWING RELATION TO PITCH-LINE VELOCITY OF BREAKING LOAD REDUCED TO STANDARD MODULUS OF 56,300 LB. PER SQ. IN.

((1) Maag gears, (2) B. & S. milled gears, (3) Mismated gears.)

EXPLANATION OF CURVES

The results of the tests given in Table 1 are shown graphically in the curves of Figs. 4 to 8, inclusive. Figs. 4, 5, and 6 show a comparison between the actual breaking loads and the breaking loads as corrected for variability of material by reducing the modulus of flexure for each set of gears to the value of 56,300 lb. per sq. in. found as an average for the entire set of gears.

An examination of these curves shows that the reduction of these values to a uniform modulus greatly improves their smoothness, as of course such a correction should.

In Fig. 5 there will be noticed a dash-line dip in curve 1. This

TABLE 1 RESULTS OF TESTS AND REDUCTION OF BREAKING LOAD TO UNIFORM FLEXURAL STRENGTH

Test No. and series	Actual flexural strength, average of 2 gears	Actual breaking load at pitch line, lb.	Actual velocity at pitch line, ft. per min.	Equivalent breaking load with flexural strength of 56,300 lb. per sq. in.	Remarks
			Maag Gears		
A 4	52454	1790*	946.42	....	See A 10, gears not broken.
A 8	57352	2420	915.23	2375	
A 9	53802	2270	930.24	2380	
A 10	52454	2050	930.24	2205	
B 7	60926	2200*	?	....	See B 8, motor stalled.
B 8	60926	2270	1373.9	2100	
B 9	58912	2360	1373.9	2255	
B 10	57868	2270*	1373.9	....	See B 11, brake failed to hold.
B 11	57868	2320	1373.9	2260	
C 8	61322	1620	1819.7	1488	
C 9	51542	1720	1809.0	1880	
C 10	58655	1940*	1787.5	....	See C 11, brake failed to hold.
C 11	58655	1970	1766.0	1894	
			B. & S. Milled Gears		
A 1	58054	1710	949.64	1660	
A 2	59710	1380	955.12	1300	
A 3	58869	1370	955.12	1312	
B 1	54105	1520	1403.5	1582	
B 2	65366	1690	1395.5	1458	
B 3	61940	1810	1384.2	1648	
C 1	51369	1520*	1841.3	1655	See C 2, brake began to flame.
C 2	51369	1320	1849.9	1446	
C 3	59172	1390	1830.5	1322	
C 4	47446	1320	1849.9	1570	
			"Mismated" B. & S. Gears		
A 5	56053	1310	960.4	1316	
A 6	60494	1240	960.4	1155	
A 7	56570	1170	955.12	1165	
B 4	55914	720	1448.3	726	
B 5	52244	990	1424.5	1068	
B 6	48661	990	1424.5	1145	
C 5	58293	910	1892.9	878	
C 6	52325	420	1920.1	452	
C 7	51343	750	1899.3	824	

* Run does not count.

dip passes through the mean of the three points of breaking for the 1000-ft-per-min. run. However, it is thought that the points located by testing gears 3–4 and 5–6 are too low. This was due to faulty operation of the brake at the beginning of the tests because of failure to lubricate it with oil as was done in all of the succeeding runs to prevent burning and seizing, and to produce smoother operation.

Fig. 7 shows the actual test curves drawn for a comparison of the strengths of the different types of gears at the various speeds. It will be noticed that smooth curves have been drawn as near the mean of observed results as possible in all cases. From these curves it is obvious that the Maag gears have a much greater strength than either the ordinary milled gears or those erroneously milled. This would tend to show that the more accurately a gear is milled the more power it will be able to transmit for any given speed. The Maag gears were noticeably less noisy than the erroneously milled ones, and also somewhat quieter than the ordinary B. & S. milled gears.

Fig. 8 shows a comparison of the curves for the three types of gears all reduced to the common modulus of rupture. From these curves it may be seen that the results obtained check very closely with the results obtained by Professors Marx and Cutter in their tests of 1915. That is, all curves are of the same general shape, and follow each other as closely as experimentally obtained data could be expected to check. This is especially noteworthy because of the great difference in flexural strength of the gears used in the two investigations (40,909 as against 56,320). It will be seen that the static loads of the Maag gears and the two types of milled gears do not check. It was not thought advisable to take the average of the three types in this case as the milled gears were very close together and the Maag gears higher, as shown in the illustration.

Conclusions

These tests show that inaccuracy of spacing of gear teeth materially affects their carrying capacity, particularly at speeds of 1000 ft. per min. and upward. Broadly, it may be said that at such speeds gears whose inaccuracies of spacing do not exceed 0.001 in. will carry twice the load that those having inaccuracies of 0.006 in. will; and that the strength of gears having inaccuracies of the order of 0.002 in. is just about half-way between the two. An error of 0.006 in. on this size of tooth was the extreme that the makers were willing to provide, and is much more than will ordinarily be found in first-class commercial cut gears.

It is to be noted that although the strength ratio of the most accurately to the most inaccurately cut gears is two to one (at a speed of 2000 ft. per min.), this is by no means as great a difference as some writers had expected to be shown; and it is particularly to be noted that the falling off of strength does not follow the law Mr. Wilfred Lewis[1] thought he had deduced from Lasche's discussion,[2] and which led him to the obvious error that the allowable load becomes zero at speeds of 2600 or 2700 ft. per min.

It is to be regretted that more gears were not available to test, as further checks on the tests would of course give greater accuracy. It would also be very interesting to continue the investigation above the speed attained in the present tests, but a larger motor and a more effective brake would be necessary to continue as the apparatus used was taxed to its capacity in performing the final tests, namely, those of Maag gears at a speed approaching, 2000 ft. per min.

Artificial Drying of Crops

The Institute of Agricultural Engineering at Oxford University with the financial backing of the Board of Agriculture has developed a process for the artificial drying of crops.

Briefly, the process is as follows: The crop is cut in the ordinary way, and if the weather conditions are favorable, is left out for a period of about twenty-four hours, during which time the crop gives up a considerable part of its moisture, thus rendering the subsequent artificial drying process easier. If, however, the weather is unfavorable, the crop may be carted immediately to the stack, where the drying process is prolonged. The principle utilized is the employment of air warmed by passage over a heated flue. The heat is provided by kerosene pressure burners. The warm air thus produced is blown by means of a fan into a conical central chamber, round which the stack is built. The chamber is made up of six timber supports, each about 3 in. by 2 in., which are covered by wire netting through which the air passes into and through the stack. The duct which connects the fan to the central structure may be made of metal of circular cross-section, sufficiently strong to withstand the weight of material in the stack—about 150 lb. per sq. ft.—and is connected to the delivery branch of the fan by a flexible hose, the air pressure being only from 2 in. to 4 in. water gage. The fan may be driven from any convenient source of power, such as a light tractor. The stacks should preferably be circular in form, and should contain from 10 to 25 tons of material. It is essential to the success of the process that the temperature of the air should not be above 100 deg. fahr. The time required for drying hay and cereals depends, of course, upon various factors, the chief of which are the amount of moisture in the crop dealt with and the amount of moisture in the air. Under ordinary conditions a stack containing excess moisture will gradually heat until a temperature of 120 deg. fahr. is reached. Then fermentation sets in, which causes a rapid rise to about 150 deg. fahr., a temperature that is sufficiently high to kill many of the bacteria that are responsible for the heating. At this point there is danger of another rapid rise in temperature owing to oxidation. The employment of heated air, however, tends to prevent this excessive rise in temperature, and so, it is claimed, fermentation and oxidation cannot take place.

A private demonstration of the process was given in October. The plant is inexpensive and is estimated to cost about £50. It is stated that the minimum period required for a stack of 10 to 15 tons to be handled is about eight hours and upward, depending upon the condition of the crop. It is also claimed that the rapid removal of the moisture prevents any chemical changes from taking place, and consequently no nutriment is lost. British figures showing cost per ton of hay handled by the ordinary method and artificial method are given. (*The Engineer*, vol. 138, no. 3590, Oct. 17, 1924, p. 441.)

[1] Mechanical Engineering, vol. 44, no. 12, p. 813.

[2] *Zeit. des Vereines deutscher Ingenieure*, vol. 43.

Engineering Problems of National Defense

A Brief Survey of the Major Management-Engineering Problems That Are Involved

By DWIGHT F. DAVIS, ASSISTANT SECRETARY OF WAR

THE subject assigned to me for discussion this morning, "Engineering Problems of National Defense," has, I think, a peculiarly appropriate significance. In the early days practically all engineering was military. Arms and armor were among the first inventions of man. Many miles of military roads were constructed by ancient nations, notably by the Romans. Rams, catapults, and other engines of war were highly perfected, and gunpowder and firearms had been invented by the end of the Middle Ages. The idea of applying engineering knowledge to non-military uses, however, was of slower growth. It was not until about the middle of the 18th century that civilization developed to such a stage that men began seriously to apply to the everyday service of mankind their knowledge of engineering principles. Today the situation is almost entirely reverse. Military engineering, strictly so-called, now occupies a very obscure place in the modern catalog of arts and sciences. Even the term "engineer" is no longer descriptive of a single profession. It must be qualified if we are to apply it to the life work of a single man. The several divisions which your Society has found it necessary to form to cover its activities show that engineering knowledge is now highly specialized.

My subject, from another point of view, however, embraces a very wide field. Engineering has been defined as the "art of directing the great sources of power in nature for the use and convenience of man." Until recently the emphasis has been laid chiefly upon the mechanics involved in directing these forces. The sciences of mechanical engineering, electrical engineering, chemical engineering, and of other technical branches have been highly developed. In more recent years the human side of directing has been receiving more attention. Very largely on account of the splendid pioneering of your former president, Frederick W. Taylor, a new science of management engineering has been created. As I hope to bring out in my discussion, many of the engineering problems of national defense lie at the very apex of management engineering. They embrace management engineering applied to the direction of resources and powers of nature available to a nation in order to prevent having the will of another nation imposed upon it. Of course, many engineering problems of a technical nature are encountered, but they are questions for the specialist to handle. I shall confine my discussion to management engineering in this talk.

Let me first emphasize two basic ideas underlying our plans. The first is that industrial preparedness is not preparedness for war; it is assurance *against* war. Unpreparedness has never yet averted war; rather it provokes attack. If it is realized that America is prepared, if we are ever attacked, to call to her defense every man, every industry, every resource, every dollar, we are far less likely to be attacked than if we were helpless, weak, and spineless. Industrial preparedness cannot conceivably be called militaristic; it will be a powerful factor in maintaining our future peace.

The second basic idea is this: that if we are ever forced into war, the burdens of war must be equally distributed. Industry, capitalist and laborer, civilian as well as soldier, each must do his appointed part in the national defense. We are firmly determined that if this country is ever engaged in another war, there must be no slackers and no profiteers.

There are two fundamental problems confronting a nation at war and these problems are basically different. They are

1 The Man-power Problem, and
2 The Munitions Problem.

The man-power problem is that of converting civilians into soldiers. Our military policy in this respect seems to be well established. With a small body of regular soldiers supplemented by the National Guard and the organized reserves as a nucleus, it is our policy in time of need to raise the great mass of our soldiery from our civilian population. The man-power problem is therefore largely one of the dissemination of military knowledge and the multiplication of personnel. It is the problem of the General Staff. Those who have had military experience and who are devoting their lives to the study of the military art are best qualified to settle military problems. So the National Defense Act very wisely placed the man-power problem under the General Staff. I mention it here because it furnishes the raison d'etre of the munitions problem.

The latter problem is of a different category. Troops require supplies of many kinds—food, clothing, shelter, guns, ammunition, tanks, airplanes, and a vast number of items in the enormous quantities necessary to meet the requirements of modern warfare. Military strategy is frequently governed by the amount of munitions available. Sometimes industrial conditions dictate the whole plan of campaign. Often battles are won or lost by the munition supply. An army without munitions is helpless before an adequately equipped enemy. In addition there is a distinct field which has only partially been explored which might be called the strategy of munitions. The industrial power of a nation may be more decisive for victory than its man power. So there is a separate munitions problem, as vital as the man-power problem, little understood, but of increasing importance in modern warfare.

Munitions must be created from resources available to the nation. The knowledge of existing industry and industrial processes; current information as to the natural resources available to the country; the existing transportation system and its possibilities; the latest developments in the arts and science; the advancements in the science of management and mass production, and the many other things which are necessary for the solution of the munitions problem—all these are properly the function of civilians.

So the National Defense Act wisely placed the munitions problem under a civilian, the Assistant Secretary of War. This does not mean that he is to take over the industries of the nation in time of war. His task is so to plan that every industry, every natural resource, every science and profession, every business man and laborer may meet most effectively the demands the country may make in insuring her defense. It is a matter of management engineering on a supreme scale. It is the greatest, the most complex, the most involved industrial problem that can be conceived.

Able engineers and executives will be available. Their patriotism and will to be helpful are beyond question. Their help in an emergency will be indispensable. But they can no more function without a well-thought-out organization than can the finest surgeon in the world perform a delicate operation without instruments. The many months which were lost during the World War in our industrial effort speak eloquently of the necessity for planning in peace time for our organization in national defense. If the War Department had even laid down a definite program before our entry into the World War, and had computed approximately its munitions requirements under the program, our effective entrance in the European conflict would have occurred months sooner than it did and the consequent saving in lives and money would have been enormous. In one item alone, that of leather goods, we estimate that a saving of some two hundred millions of dollars could have been made.

The War Department, therefore, must work out an organization and plans for its operation and control in time of war. It must select the personnel to man the organization; making sure that round pegs are selected for round holes and square pegs for square ones. If our organization is properly "engineered," if the selection of big business men to key positions is wisely made, our army will enter the conflict under no preventable handicap from the industrial side. Otherwise, we must expect a recurrence of many of the difficulties which were encountered during the World War.

Basically, the organization which we are evolving must be viewed

Address at the National Defense Session of the Annual Meeting of The American Society of Mechanical Engineers, December 3, 1924.

from the aspects of requirements, resources to meet these requirements, and machinery and personnel to make it effective. The mere task of computing the requirements in finished products is a large one, although it is but the first and simplest step in the problem. Let me give you just one example.

To furnish sole leather for the manufacture of sufficient shoes for six field armies would require 4,462,500 steers, while for upper leather 3,370,000 cows would be required, making in all a total of 7,832,500 head. To transport these cattle all at one time, there would be required 401,625 cattle cars—a train approximately 3000 miles long, which would reach almost from New York to San Francisco.

If the cut soles were placed in a pile one on top of the other, a stack of soles 375³/₅ miles high would be the result; more than 68 times higher than Mount Everest, the highest mountain peak in the world, or 3573 times higher than the Washington Monument.

If the upper leather required were made into a belt 1 ft. wide, this belt would reach entirely around the earth at the equator, with enough left over to run a belt line from New York to San Francisco. If these service shoes were placed in a straight line heel to toe, they would extend a distance of 12,960 miles, or halfway around the globe.

After these requirements have been computed they must be translated into terms intelligible to industry. We must know what they mean in terms of raw materials, machine tools, gages, shop equipment, power, labor, transportation, and everything else that industry is to be called upon to furnish to meet our demands. Each of these is a distinct problem, many of them of great complexity.

For example, the subject of resources available to the United States with which our requirements can be met is a difficult one. Numerous government and private agencies collect statistical data which are invaluable to the officers of the War Department engaged in this work. Many contacts also have been made with leaders in American industry who are coöperating in the resource studies which have been undertaken. Among these I may mention in this connection a very valuable report on the manganese situation made by a committee of the American Institute of Mining and Metallurgical Engineers, the Nitrogen Survey recently published by the Bureau of Foreign and Domestic Commerce, to which several governmental bureaus contributed, and the work being done by your own society toward securing an index of American engineers which will be available to the War Department to assist in the selection of proper individuals for key positions.

We have recently appointed fifteen commodity committees to which has been assigned the task of getting together the total requirements of all supply branches for certain assigned commodities. Having ascertained the total requirements, the committee submits them to a designated supply branch. It is the duty of this branch to maintain contact with the industry and to make a plan for procuring the commodity in time of emergency. This plan is then cleared by the commodity committee, and when satisfactory becomes the procurement plan of the War Department for the commodity.

It is planned to increase the number of these commodity committees until all commodities, the procurement of which may be difficult in war, are covered. If war came, their membership would be increased by calling to the colors commodity experts who have been selected in time of peace because of their particular fitness for the work. These committees will work in harmony with whatever committees may be formed by a super-agency to control the entire solution.

The other problems I mentioned are being studied in a similar way. The transportation difficulties will be worked out by committees of railroad men, labor problems by labor leaders, and so on through the list. These plans are not merely War Department plans alone. They are the concerted effort of American industry to do its part in the national defense.

I have tried to give you an idea of our major problems in management engineering, without going into details as to the plans. There are, of course, an infinite number of lesser problems which have to be taken into account. However far we carry our planning, we must remember that all planning contemplates eventual action, if this should ever become necessary. Planning alone will not produce a single round of ammunition or one airplane. It is only in so far as our plans are capable of being carried into effective production that they are of value. The industrial-preparedness problem is "our" problem—yours as well as mine. The War Department solution is no solution unless it has the active support of the engineers and industrialists of America. In time of peace we are most grateful for the aid and encouragement you are giving us. In the unhappy event of war, I know that we shall have your help and coöperation in executing it. It is our joint responsibility to flag and country.

A Place for Safety

A General Discussion of the Accident-Prevention Movement

By LEWIS A. DEBLOIS,[1] WILMINGTON, DEL.

The title of this address I have purposely left general—even vague—for I desired to discuss the accident-prevention movement, or, as we call it, "safety," in broadest terms. To get a true conception of its significance in life and of its place in or connection with the science and profession of engineering requires some breadth of vision and sense of perspective, without which only the superficial aspect (with which you are already familiar) would be revealed. I felt, moreover, that a general and discursive paper is sometimes a desirable variant from the precision and intensity of a technical program.

In the first place, I would like to dispose of certain fundamental matters in order that we may proceed in step upon our mental travels. If we, as a part of the great majority, define "safety" as "not getting hurt," we at once admit its very ancient origin and recognize the desire of its attainment as a directive force in every age and throughout all living conditions. It is the expression of the elemental instinct of self-preservation and as such is essentially selfish. The modern paraphrase is "Safety First," and it is generally used to mean the safety of the individual first and every one else second. That in itself is, I believe, one good and sufficient reason for discarding the expression as rapidly as can be done. The French equivalent, *"sauve qui peut,"* is only slightly less selfish! It happens, however, that the safety movement is not selfish but essentially altruistic and, as a matter of fact, "not getting hurt" is merely the result of what we today call "safety" and is not safety itself. Safety is the existence of those mental and physical conditions which make the occurrence of accidents improbable.

From an engineering aspect the process of living appears to consist in general of two stages not necessarily consecutive: a development stage during which research and experiment go on, followed by the selection and retention of what is conceived to be of lasting value; and a productive stage wherein the retained knowledge is applied and those things that are of use to the race or to the individual are produced. This is certainly true of industry and the masses engaged in it, and seems to me equally true of the individual if we consider that education and the acquiring of experience in the broader sense represent the development stage. Between those two stages an important difference exists: in the case of production,

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uniformity, continuity, and orderliness are desirable and often indispensable; in the development stage they may be unessential and even destructive. Permit me to explain.

As engineers we have been engaged to develop a certain manufacturing process and establish it on a paying basis. In the development stage we must conduct research and experiment. While it is obvious that our method of going about it should possess continuity and orderliness, we must of necessity avoid unnecessary repetition, apply our imagination and the experience of others, accept inherent hazards, and expect occasional disappointments and failures. In this stage we are in a sense pioneers and must depart from the traveled highways. But when our process has been discovered and the method of its application determined, we shall surely bend our efforts toward making production efficient, continuous, and of a uniform degree of excellence. So much for industry.

As an individual I am engaged in developing my character and establishing it on a paying basis. In the development stage I must receive an education from others and also learn from direct experience myself. While it is obvious that the educational method, at least, should possess continuity and orderliness, I must avoid unnecessary repetition, apply my imagination and the experience of others, accept inherent hazards, and expect occasional unpleasant results. In this stage I am often a pioneer and must depart from the traveled highways. But when I apply to life the results of my education and experience, I must bend my efforts to a continuous, uniform, logical, and efficient application. I must not be "penny wise and pound foolish;" I must not "strain at a gnat and swallow a camel"—in fact, I must observe all the laws and aphorisms and limitations of human nature that knowledge and experience have taught me.

You see that in the latter paragraph I have paraphrased the industrial example almost word for word. In truth, the only real difference appears to lie in the fact that development and production are almost always continuous and often simultaneous in the case of the individual, while in the case of industry development is generally abandoned as soon as the production stage has been reached.

Reviewing the situation: We have, first, the stage of development in which exploration and pursuit of experience is to be encouraged; and second, the stage of production in which departure from the normal is out of place and orderliness and repetition make for efficiency.

An accident, according to Webster, is "an event that takes place without one's foresight or expectation." Obviously, this implies a departure from the normal and orderly procedure upon which the efficiency of production to a great extent depends. Accidents therefore tend to lower production efficiency. On the other hand, many great and valuable discoveries have been made accidentally, and many happy and profitable experiences come to us, as we say, "by accident." This, however, has to do with the stage of development and not the stage of production. Can we not say, then, that accidents sometimes promote development and proceed to ask ourselves, "When do they promote it and when retard?" A comprehensive answer to this question is difficult to find, and I shall somewhat beg the question by merely asserting that development is promoted when the experience gained through the accident is worth while and retarded when not worth while.

It will perhaps clear our thoughts if we set down the foregoing in concise statements, as follows:

1 Accidents lower production efficiency.
2 Accidents tend to promote development so long as the experience gained thereby is worth while.

We have been discussing accidents and not the physical injuries which arise from accidents. Bear in mind that the same accident may be repeated many times without resultant injury and, in fact, may never cause an injury, but in so far as production is concerned, efficiency is always affected by the occurrence of an accident whether injury follows or not. This explains some of the extraordinary savings that have attended the introduction of successful injury prevention in industrial plants. I have in mind a certain punch-press operation which had resulted in the loss of many fingers when caught between the dies. A device was finally applied which prevented not only these injuries but the accidents which sometimes—and only sometimes—caused them. The prevention of the injuries saved compensation expense, but the prevention of the accidents increased the press output fifteen per cent. It had eliminated some unsuspected source of production inefficiency. This was a conspicuous example; I could name others; there have probably been thousands not recognized as such. Out of such experience has come general acceptance of the statement that "a safe plant is an efficient plant," first pronounced by safety enthusiasts who at the time little understood the great truth underlying their statement. Again and again I have seen it demonstrated in operations, even of the most diverse sorts, and also in construction work. I believe we may carry the thought outside the plant fence and beyond the construction project and say with equal truth that the safe city is an efficient city and the safe home is an efficient home, for are not traffic accidents largely the direct outcome of automotive-transportation inefficiency which is causing in our cities today incalculable waste of time and enormous public expense, and is not "good housekeeping," which is inseparable from industrial-plant efficiency, equally inseparable from household economy?

If, as I believe, these things are true and a recognition of them is of such fundamental importance, especially to the engineer, how comes it that we have been so slow to grasp their true significance? In the first place, I suspect that no one has as yet successfully let in the light upon the superstition that accidents happen fortuitously. The race still believes individually in its luck or ill-luck. It is true that the causes of injuries are frequently obscure or complex and that we are inept at calculating compound probabilities, and this may be the reason why we do not learn the astounding lesson now being taught us by those industrial establishments which have had mature accident-prevention experience—the lesson that when all, or almost all, employees have become truly interested in safety and a real coöperative effort is under way injuries from all types of accidents cease for periods as great as 3,000,000 man-hours. It is superfluous to ask whether such an accomplishment could be possible if accidents merely happened—indeed it constitutes the most convincing proof that accidents are caused and that the causes are removable!

Failure to grasp these essential facts may also be due to superficial accident investigation or to confusing the proximate causes of accident and injury. For example: an employee's arm is caught between a belt and pulley while applying belt dressing. Obviously the injury is caused by contact with mechanical forces to which the body can offer but little resistance. At the moment of contact the belt may leave the pulley, but the mechanical efficiency of the transmission is, in the aggregate, but little disturbed. Future contact will be rendered less likely by installing a proper belt and pulley guard. This is the obvious analysis of the situation and the usual remedy, but note that it has to do solely with the cause of physical injury. Closer investigation and analysis deal with the circumstances leading up to the application of belt dressing, in other words, with the cause of the accident. We find, perhaps, that it was applied to remedy slipping and that slipping was due to overload or faulty design of the transmission. Here we find a major and continuing source of inefficiency in the slipping belt as against the minor and momentary inefficiency that occurred at the time of the injury. Moreover an overloaded belt is wasteful, for slipping may shorten its life forty per cent or more. A guard around the pulley only makes matters worse, and if it has to be removed frequently in order to replace the belt it will be continually found out of service, in which event the original situation has not been materially benefited. The proper correction is to substitute a wider belt.

I trust it will be observed that the preceding example touches the field of engineering design—in fact, there is hardly a type of accidental injury the prevention of which does not have its engineering aspect. The proximate cause of the oiler's death was his fall from a defective ladder—which he might not have used had he been imbued with the thought of safety—but fundamentally the fault lay with the engineer whose design omitted the provision of a proper oiling walkway; the machinist's sleeve was caught by the jaws of the chuck and his arm broken—he should not have worn loose sleeves—but it was the design engineer who located the motor control so that the machinist would be impelled to reach across the revolving chuck; the coal passer was suffocated and crushed by the coal within the hopper into which he should not

have gone to break up a "bridge" without the protection of a life-belt and line, but the design of the hopper was faulty and every bridging with or without an accident was inefficiency. These are not unusual examples but common and typical. Unfortunately the average engineer—and I speak with some knowledge and no little regret since I am also an engineer—directs his attention to perfection of mechanical design and the efficiency of mechanical operation and has a tendency to overlook the lessons that lie below the surface of the commoner accidents. There appears to be some reason for supposing that the safety movement may have been responsible for saving some 240,000 human lives during the past 14 years. Far from becoming exhausted by its own enthusiasm or exhausting the field of possible accomplishment, it is certainly expanding and pervading human life at an astonishing rate. We cannot afford to accept its existence carelessly, since within such a movement as this, quite unique in the history of the world, may lie innumerable lessons of very real significance.

Before closing I desire to return to my earlier hypothesis: that accidents, though lowering production efficiency, tend to promote development so long as the experience gained thereby is actually worth while. I take it that an accident which causes physical injury is never worth while if the experience benefits only the individual, since even the most trivial injury may through infection, etc. terminate fatally, and in such case the gain in experience is offset and the affair must be entered as a net loss. But if another's life is saved or the race is benefited or human knowledge receives a valuable accession the experience, from the broader viewpoint, may be accounted worth while. On the other hand, I believe that such cases are exceptional and that the worth-while accidents are those that entail no physical injury. In daily life we do not call them "accidents," however, but experiences or adventures, and they are the very zest of life and perhaps its inscrutable purpose. It is only from them or from the experiences and adventures of others that we go forward. This constitutes the development stage that I have spoken of, while the production stage is merely the application of such learning to life. The production or application stage may and should be standardized, but any attempt to standardize development is fatal, since it inhibits adventure and experience.

The greatest resistance to the safety movement has come from the feeling that it is a dead-leveling process, inducing fear of chance-taking, discouraging adventure and, to use a current expression, "always taking the joy out of life." To a certain extent this is true in respect to the routine of life, which needs to be standardized for the sake of efficiency in order that we may gain greater opportunity for development; but in matters of individual and racial development it encourages the pursuit of adventure and the acquisition of experience—with the proviso, however, that the hazards of the undertaking shall be recognized and understood in order that the experience, unmarred by physical injury, shall be ultimately worth while.

Elimination of National Waste[1]

IN COOPERATION with commerce and industry to advance productivity, the U. S. Government, through the Department of Commerce, has developed a definite constructive national program for the elimination of waste in our economic system. The need is plain. The American standard of living is the product of high wages to producers and low prices to consumers. The road to national progress lies in increasing real wages through proportionately lower prices. The one and only way is to improve methods and processes and to eliminate waste. Regulation and laws are of but minor effect on these fundamental things.

There are wastes which arise from widespread unemployment during depressions, and from speculation and overproduction in booms; wastes attributable to labor turnover and the stress of labor conflicts; wastes due to intermittent and seasonal production, as in the coal and construction industries; vast wastes from strictures in commerce due to inadequate transportation, such as the lack of sufficient terminals; wastes caused by excessive variations in products; wastes in materials arising from lack of efficient processes; wastes by fire; and wastes in human life.

[1] Extracts from the 12th Annual Report of the Secretary of Commerce, Herbert Hoover.

Against these and other wastes the Department of Commerce has for the past three years developed an increasingly definite program.

Unemployment. The First National Conference on Unemployment, called in 1921, produced successful relief measures, and demonstrated that exhaustive investigations should be made of the whole problem. A committee of business men, labor leaders, economists and engineers collaborated in this study, and this report did much to curb the beginnings of a dangerous boom in the spring of 1923.

Seasonal Construction. A committee reporting on this showed conclusively that custom, not climate, is mainly responsible for the ups and downs in building, and that these evils are largely unnecessary and can be eliminated. For most types of construction it is now possible to build the year round in the United States. The value of yearly construction in this country is over five billion dollars. If building falls off, there is always a slackening in many other lines of industry, resulting in unemployment, decreased purchasing power of employees, and further depression.

Important action has now been taken in many communities in changing leasing dates and in other devices to induce more regularity to construction.

Bituminous-Coal Industry. Investigation revealed the high instability of this industry and the fact that it was functioning at great material loss. Due to the war and to periods of profiteering far too many mines had been developed and placed in operation.

The primary remedies needed in this industry were better transportation, reduction of seasonal character of industry, summer storage of coal, and industrial peace. Through an application of these the industry is now on the road to stabilization.

In this industry, the past year, as compared with the year 1920, shows a saving to the consumer of about one billion dollars, which must be reflected in decreasing costs of production in every avenue of industry and commerce.

Superpower. Engineering science has brought us to the threshold of a new era in the development of electric power. This era promises great reductions in power cost and wide expansion of its use. Fundamentally, this new stage of progress is due to the perfection of high voltage, longer transmission, and more perfect mechanical development in generation of power.

The Northeastern Superpower Committee, with its engineering sub-committee, reported in April, 1924, dealing with the major steps necessary to bring about the technical development required, and already a number of these steps have been undertaken by the various power systems throughout this area.

Purchasing Specifications. The war showed that the faultiness of specifications used in Federal purchases resulted in great waste of public funds.

The Federal Specifications Board was established to take the multitude of specifications in hand, and the manufacturers are being brought into consultation to make sure that the industrial and commercial setting of a given specification is right from the point of view of the practical producer. In this manner a complete revision of Government specifications is under way, 210 such standard specifications having been prepared up to the present time.

A specific saving is in the wearing parts in automobiles, and a computation made by manufacturers shows that the benefit to the public automobile user through the longer life amounts to a saving of at least fifteen million dollars a year.

Improvement in Technical Processes. Many of the small manufacturers who cannot afford to establish the laboratory and research staff necessary for consideration of broad problems now use the Bureau of Standards in researches into the elimination of waste in industrial processes.

Instances of such researches of public interest are reduction of losses in the baking of Japan ware and in the installation of an optical-glass industry.

Simplified Practice. A large field in the elimination of waste lies in the direction of simplified nomenclature, grades, and variations in dimensions of industrial products. The Division of Simplified Practice, established in 1921, serves as a centralizing agency in bringing together producers, distributors, and consumers for the purpose of assisting these interests in their mutual efforts to eliminate waste in production and distribution.

The Carnot Centenary Commemoration

Arranged by the Engineering Foundation on Behalf of the Founder Engineering Societies and Certain Other Scientific Bodies

THE Carnot Centenary, held in the auditorium of the Engineering Societies Building on the evening of Thursday, December 4, was an interesting and notable occasion. It was a tribute of American engineering and science to Sadi Carnot and the announcement of the Carnot Principle, otherwise known as the second law of thermodynamics. This great principle was published by Carnot in 1824 when he was only 28 years old. He lived only eight years afterward.

The law was first set forth in a modest paper of a few pages, and it was more than twenty years before any one appreciated or understood it. It is now recognized as one of the great fundamental laws of modern science, like the laws of gravitation and of conservation of energy. It is fundamental to clear thinking in dealing with the transformations of energy throughout the whole field of science and engineering. It was the work of a genius, as it antedated by many years experimental confirmation.

The celebration was arranged by the Engineering Foundation on behalf of the Founder Engineering Societies and certain universities and scientific bodies interested. Dr. W. F. Durand, President of The American Society of Mechanical Engineers, presided at the meeting and introduced the speakers of the evening. The French Government and French science were represented by M. Paul Gripon, Naval Attaché at the French Embassy in Washington, who brought the hearty thanks of the French Embassy for the commemoration of the publication of Carnot's book on Power of Fire; and by M. Jules J. Champenois, Director in the United States of the National Bureau of French Universities, who read a message from Dr. Charles Fabry, one of the most eminent of present-day French scientists.

Doctor Fabry in his letter expressed his heartfelt appreciation of the homage thus paid to Carnot's memory. Many discoveries, he said, had been made in the course of the 19th century, but Carnot's discovery had come about in such a way that it must be considered as a unique event in the history of science. Some discoveries had been made because they had been the logical outcome of what had been accomplished before; in such cases, the scientist's genius had anticipated but by a few years the necessary course of things. Other discoveries had been due to chance only; it had happened that certain elements were brought together but, necessary as they were, such happy coincidences were bound to occur sooner or later. Carnot's discovery belonged neither to the former nor to the latter kind; it owed nothing to chance; it had been so unexpected and even so difficult to comprehend, when it took place, that it had nearly run to waste. In fact, it would have done so but for the devoted friendship of Clapeyron and the foresight of William Thomson (Lord Kelvin) who was actually the discoverer of Carnot.

Doctor Durand spoke in part as follows:

"This occasion is one of a type which too rarely finds a place in the hurried rush of our modern life. For the most part we are too much occupied with present-day affairs and with attempts to discount the future, to find time for contemplation of the past, for an acknowledgment of our indebtedness to the great minds of former ages, or to give due honor to their names.

"This evening and these exercises form, however, a happy exception to this too common failing of our present-day life. We are met for the specific purpose of contemplating the past, of acknowledging our indebtedness to a former age and of doing honor to a great name.

"If we could gain some faint concept of the debt which the present age owes to Sadi Carnot and to the principle which he first (now 100 years ago) enunciated in full and complete form, let us ask of ourselves the question: To what extent do the elements of our daily life depend upon the utilization of power? To what extent are we thus dependent for food to eat, for clothing to wear, for shelter from the elements— in short for all our material possessions—again for facilities of travel and the interchange of commodities over the earth's surface; for facilities of communication with our fellows by mail, by telegraph, by telephone, by radio—and in short, for the distinctive elements which go to make up the material content of our present-day civilization? To what extent are we dependent for all these upon the utilization of power—the useful application of the energies of nature to the requirements of our civilization?

"And, then, with faint image of the extent of this dependence forming in the mind, let us ask a second question: What part of this dependence traces back to *heat* as its source—heat from coal, from gas, from petroleum oil and its derivative products? The answer to this query forms even as the question is asked, and we

Sadi Carnot at the Age of 17; Portrait by Bailey, 1813

recognize the fact that in overwhelming proportion the power required to produce and maintain the material content of our present-day civilization traces back for its source to that great undifferentiated ocean of energy embodied in molecular agitation, and which we know under the name of heat.

"The measure, then, of this dependence on power drawn from heat as a source is the measure of the obligation which we owe to do honor to the name of Sadi Carnot."

The two principal addresses were delivered by Dr. M. I. Pupin, professor of electromechanics at Columbia University who spoke from the standpoint of the pure scientist, and by Dr. Wm. LeRoy Emmet, consulting engineer of the General Electric Company, who spoke on behalf of the engineering profession.

Extracts from these two addresses immediately follow.

Carnot's Principle

By M. I. Pupin,[1] New York, N. Y.

ONE hundred years ago a principle was discovered which marked the beginning of a new era not only in the history of science, but also in the history of all human thought. Its great discoverer was Nicholas Leonard Sadi Carnot, and hence the name Carnot's Principle. The fame of the discoverer has never passed beyond the boundaries of a comparatively small circle of scientists and engineers. This may seem strange, but it is not as strange as the historical fact that it took fully twenty-six years before that discovery could find its way even into the tiny circle of the foremost scientists of Europe. The reasons for this delay of recognition are not far to seek.

Carnot's Principle, as originally formulated by the discoverer, is the only trusty guide in our studies of the operations by which heat is harnessed to do mechanical work and render service during its passage from a higher to a lower temperature level, an operation so well illustrated by the performance of the steam engine. But in order that heat may perform that service it is necessary to guide it in its passage from higher to lower temperature levels by a suitable mechanism, and Carnot described an ideal mechanism by means of which the maximum service is obtainable. Carnot was only a youngster of barely twenty-eight, and perfectly unknown to the academicians of France, when in 1824 he published his epoch-making essay On the Moving Power of Fire. The concepts of "work" and "energy," so clearly defined in Carnot's mind, had only just begun to find their way into scientific thought, so that as we look back today we cannot help thinking that Carnot was far ahead of his time; he was a prophet, and a prophet is always hard to understand. Hence the long delay of recognition—it came nearly twenty years after Carnot's death in 1832, when he was only thirty-six years of age.

The prophet differs from the ordinary man by the intensity of the impressions which environment makes upon his mind. He is a man of inspiration. What inspiration guided Carnot in his prophetic thoughts? Was it the operation of the steam engine and nothing else? I do not think so, but even if it had been so, then another question would arise, namely, what inspiration guided the inventor of the steam engine? I shall now touch upon a subject so well discussed last Tuesday by Dr. Low, the retiring president of The American Society of Mechanical Engineers.

We recognize today that there is, as Dr. Low said, a cosmic stream of solar energy from which everything that lives and breathes on this terrestrial globe derives its driving force, just as the mill on the mountain side derives its driving power from the mountain stream. This cosmic stream of energy is the mighty flow of solar radiation. The oceans catch it and derive from it the lifting power of their vaporous water masses, which, driven by atmospheric currents, distribute their precious loads over the thirsty continents. Countless billions of drops of water are thus carried by solar radiation to the highest continental elevations, and before they return to the oceans again each one of them has performed a definite mission. No relief expedition has ever performed a more precious service to terrestrial life than these tiny messengers of our terrestrial oceans. If science could find a Homer who would describe in suitable language the adventures of some of these drops of water on their cyclic journeys from the oceans to the continents and back again, the world would read an epic alongside of which Homer's Odyssey would sound like a commonplace and vulgar tale. This Homer of science has not yet been found, although five thousand years ago the poets of the Rigveda and the Mahabarata told us that in those days man's mind saw in this solar-energy stream and in the service which it rendered to terrestrial life a new divinity and founded a religion of solar worship. This was the result of the ancient inspiration.

Contrast now with this ancient mind the modern mind of the inventor of the steam engine. Where one saw the resplendent sun god, the other saw a celestial fire and imitated it by a terrestrial fire under a boiler. Where one saw the blessings of the sun god, manifesting themselves in the healthy growth of terrestrial life, the other saw evaporation of the oceans and the gigantic mechanism which lifts the enormous water masses destined to irrigate the continents; he imitated it by providing the boiler of the steam engine which, by the pressure of its steam, drives the piston of the steam engine and does work which relieves man of his heaviest burdens. The cosmic operation as well as its tiny terrestrial imitation, the steam engine, employs the same cyclic process of harnessing heat in its passage from higher to lower temperature; levels for the purpose of making it serve man just as the mountain stream in its downward course serves the happy miller on the peaceful mountain side. But neither the ancient sun worshiper nor the modern inventor of the steam engine knew anything about the fundamental law in accordance with which heat performs this precious service to man. The revelation of this simple truth was reserved for a prophet who had the vision to see a new truth in physical phenomena which have become commonplace, because from time immemorial they have surrounded us on every side and all the time.

Now what is the fundamental truth which Carnot extracted from the familiar phenomena which accompany solar radiation and the operations of a steam engine?

The first part of this truth was an axiom, that is, a self-evident truth, and it is this: "Heat cannot perform mechanical work except when it passes from a higher to a lower temperature level." Carnot illustrates this axiom by pointing out that, similarly, water stored in a reservoir cannot do external work except when it passes from its own to a lower level.

Wherever, therefore, there is a difference of temperature levels there is a possibility of harnessing heat for useful service during its passage from the higher to the lower level. The blessings conferred upon our terrestrial globe by solar radiation undoubtedly helped to suggest to Carnot this self-evident truth. The axiom itself cannot fail to remind us that there are billions and billions of blazing stars whose temperature levels above the surrounding space are much higher than that of the sun, and are therefore capable, each of them, of rendering similar service and to a similar extent as the sun. The sight of the stars should therefore remind us that there are in the physical universe inexhaustible stores of opportunities for rendering service similar to the service which solar radiation is rendering to our terrestrial globe. With this axiom in our mind we shall always find the word "service" written across the starry vault of heaven. When the psalmist sings, "The heavens declare the glory of God," remember that in this declaration the word "service" is the biggest word.

It is a matter of universal experience that direct conduction of heat from a hot body to a cold body in contact with it will produce no other effect than to raise the temperature of one and lower that of the other. No mechanical work is done under these conditions and, therefore, no service is rendered which forms the subject of Carnot's philosophy. When, however, we interpose a suitable instrumentality in the path of heat which is being transferred, then service may be rendered. This is what we call the "harnessing" of heat. The piston in the cylinder of the steam engine is such an instrumentality, it is a part of the harness. The steam in the cylinder expands and drives the piston against external pressure and thus performs work at the expense of a part of the heat of the steam, the other part passing on to the condenser. The steam engine with its well-known cyclic operations is a crude illustration only of what Carnot meant by an instrumentality which enables heat to render service during its passage from a higher to a lower temperature level. Carnot himself described a much more perfect instrumentality for these cyclic operations: it is a steam engine idealized in its construction as well as in its mode of operation by expansion and compression.

It is not necessary to go into any detailed description of Carnot's poetic conception shown in his ideal engine and its ideal cyclic operations except to say that they are reversible. That is to say, if the heat is passed from a higher to a lower temperature level and a certain amount of work is delivered by Carnot's engine, then when the cycle is reversed the same amount of work delivered to the engine will transfer to the higher temperature level the same amount of heat; otherwise a *perpetuum mobile* would be possible, and that, following Newtonian dynamics, Carnot rejects as impossible. Carnot shows then by the simplest kind of logic ever employed by

[1] Professor of Electromechanics, Columbia University.

Extracts from an address at the Carnot Centenary Commemoration, Engineering Societies' Building, New York, December 4, 1924.

a scientific mind that under these ideal conditions the maximum amount of mechanical work is obtained by the passage of a given quantity of heat from a given higher to a given lower temperature level, and that this maximum depends upon the initial and the final temperature and upon nothing else. This is Carnot's Principle. It can therefore be summed up briefly as follows:

> Heat can do mechanical work by passing from a higher to a lower temperature level, if suitably harnessed. When that passage is effected by means of a reversible cycle, the maximum amount of work will be obtained, and this amount will be independent of everything except the initial and the final temperature.

Twenty-six years elapsed before the full importance of this principle was clearly understood. Young William Thomson, who later became Lord Kelvin, but who at that time was only twenty-six years of age, was the first to decipher Carnot's message, and this enabled him to construct a new and absolute scale of temperature. It was then an easy matter to express Carnot's Principle in the various mathematical forms known today as the Second Law of Thermodynamics.

The first advance upon Carnot's work was the result of many efforts, especially notable being those of the great Maxwell, to explain dynamically the efficiency of the transformation of heat into mechanical work as demanded by the second law of thermodynamics. The first result of these efforts was the confirmation of an old belief that heat is a non-coördinated mode of molecular motion. This was vaguely suggested by many scientists of the eighteenth century.

The molecular motion in a hot gas offers the simplest illustration. We call that motion "non-coördinated," because each molecule, being practically an independent unit, performs its motion according to its own sweet will, colliding incessantly with its neighbors. It is a chaotic state of motion, and we can say that among the enormous number of molecules contained in a cubic foot of a hot gas there is a chaotic distribution of kinetic energy. The function, then, of Carnot's piston is to receive the impulses due to this chaotic mode of motion and to transform them into a coördinated form of motion of the machinery connected to the piston. This is indeed a transformation of a chaos into a cosmos, and the highest efficiency obtainable by man is that given by Carnot's Principle.

The chemical energy of a finite mass is also distributed among an enormous number of atoms. When these atoms unite in a perfectly unrestrained way we have again a chaotic distribution of activity, each atom jumping, so to speak, in an unrestrained way into the arms of the atom with which it unites and generating heat, just as a weight freely falling to the ground will generate heat by impact. But, as was pointed out by Thomson over seventy years ago, when a galvanic cell is the seat of chemical reactions and as a result of them external work is done by employing the generated electrical power to drive a motor, then the dissipation of chemical energy into heat may be very greatly reduced. The galvanic cell may therefore be called a coördinator of the chemical activity in the same sense in which that name has been applied to the function of the Carnot piston. This indicates roughly how Carnot's principle has found its way into the study of chemical reactions so beautifully worked out by Willard Gibbs.

The more one studies Nature the more clearly does he see that everything has a granular structure. There are the granules of matter, the atoms and the molecules. Then there are the granules of electricity, the positive and the negative electrons. Then, again, there are the granules of life, the cells and the millions and millions of their constituent parts. Finally there are the nations with their millions of human granules. Each granule has an individual and more or less autonomous existence. A chaotic, a non-coördinated activity results unless coördinators are introduced which transform the chaos into a cosmos. I do not think that I am too optimistic when I say that some day Carnot's Principle will help us to understand these complex activities of life in the same way that it has helped us to understand the phenomena of heat, radiation, and chemical action. At any rate I do not see any other scientific principle which unites the activities of the inorganic and organic world under one general and all-embracing concept.

Carnot's Influence upon Engineering

BY WILLIAM LEROY EMMET,[1] SC.D., SCHENECTADY, N. Y.

CARNOT was a demonstration of quantitative relations in physical science. Such work is generally done by students who seek truths for which, in their time, there may seem to be no demand, and the importance of which can be appreciated by few, if any, of their associates. The relations which they perceive and evaluate may be simple but they are unseen, and calculations must be based upon mental pictures which can only become clear and definite through thoughts for which the faculty must be given not only by nature but by the practice which brings facility in every unusual mental process.

The function of such men is quite different from that of men who assume large responsibilities in engineering and who may produce visible results which are more conspicuous. They are generally students connected with institutions of learning or, like Carnot, with scientific departments of some government. Even if such studies constitute this official business, they must be impelled by an inward fire which drives them to heavy tasks for which there may be little reward other than the joy of building.

The duty of the engineer is to go as deep as his undertaking requires and to trust no knowledge which is not firmly established. His dealings are with values, and with other people's money, and his best guide in his profession is a good perception of the dangers of error. He must work with such knowledge as is recorded, or must extend and verify it by experimentation. If he seeks to do anything difficult, or new, he will generally find that little of the recorded knowledge is correct or accurate enough to be safe for his use. If he seeks the truth, therefore, he will feel abounding gratitude to the great men like Carnot who have given him a few laws which are fundamentally correct and susceptible, in principle, of universal application.

The science of thermodynamics is, by its nature, difficult of mathematical analysis and of experimental verification, and those of us who work with it can revere the names of the great men who have put it within our grasp. Many have contributed to the work, but the thoughts of English-speaking engineers naturally turn to William Rankine, that Admirable Crichton of Engineering, and to the great William Thomson, whom we have latterly known as Lord Kelvin.

Thomson was, the speaker believes, the first to complete the statement of Carnot's function and identify it with the absolute temperature scale. Rankine made the calculations upon which our uses of steam are based. The modern engineer has but to devise means by which the possibilities pointed out by these great men can be accomplished; additions to their knowledge in the matter of thermodynamics being matters of accurate experimental determination rather than of extension of principles.

The history of steam and of heat engines has been a great one and many strong men have contributed to it. Many of its landmarks have been written into the textbooks and are more or less familiar. Many of the advances have been made by men who did not fully understand the theoretical merit of their improvements, but the good, practical engineers generally know more than they write, and have partially developed theories, based upon comparison and analysis of facts, which are sufficiently near the truth to afford safe bases of action.

Watt developed the steam indicator, and its records gave him a good idea of the steam possibilities. He lagged and steam jacketed his cylinders, knew the losses incident to cylinder condensation, invented the condenser, first used the air pump, and undoubtedly knew, with a fair degree of accuracy, the possibilities within the range of his experience. Watt was a wonderful and eminently practical man, and used most of the devices which make up engine practice today. There had been little need for the kinds of shop work required for his engines and he had to do much to develop manufacturing facilities. Notwithstanding all this advance, and the great uses in industry which rapidly developed, many years elapsed before the possibilities of steam uses were correctly understood.

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Address at the Carnot Centenary Commemoration, Engineering Societies' Building, New York, December, 4, 1924. Slightly abridged.

Watt seldom used steam pressures above 7 lb., and it was not until about 1860 that pressures as high as 50 lb. were employed. The demonstration of the true theory of steam probably contributed to the efforts for higher pressure, and to a great increase in the use of compound engines.

Engines of very primitive type still exist and remind us of the rapidity of the advance of engineering. Many of our steam-boats still use about 40-lb. steam pressure and engines about like those of Watt. A friend of mine bought an old mill site in England and in it, among other curiosities, was an engine with a wooden cylinder.

When Watt began to introduce his engines commercially, he replaced primitive mine-pumping engines of the Newcomen type and took as his pay a proportion of the fuel saving accomplished. This same thing was done by Corliss when he began to put his engines into New England mills.

Corliss made a substantial improvement by making a type of valve which would work and give an ample opening with a relatively small clearance, and by so arranging his mechanism that he could govern by varying the cut-off, which was made quick and definite. The gains immediately justified the throwing out of old engines and substituting new in many cases.

Fuel economy is so important that it seldom pays to use any engine but the best. In a 60,000-hp. transatlantic liner a variation of one per cent in engine efficiency will mean something like $15,000 in annual fuel cost, without considering the cost of carrying the added fuel—which may be very appreciable.

The large compound Corliss engines, rated 5000 kw., such as were installed when the New York Elevated roads were electrified, were the best engines existing when the steam turbine began extensively to replace the reciprocating engine as a source of power from coal. One of these engines working with its best adjustment and at about 4000 kw., with 175-lb. steam, used 17 lb. of steam per kw-hr. output. When run with equal load on the cranks and with 6000 kw. output, which about represented common practice in the use of such engines, the consumption was 19 lb. per kw-hr. The falling off of economy with increase of load illustrates the limitation of the reciprocating engine which, through lack of low-pressure cylinder space and valve area, is incapable of much expansion in the steam, and therefore cannot work effectively through a wide temperature range. The best large turbines today, running under this condition with a good vacuum, would use 13.7 lb. of steam—a gain of about 30 per cent; but since they would be run with much higher pressure, high superheat, and more advantageous feed-heating conditions, the gain would be at least 50 per cent. With the latest developments of high steam pressure it would of course be considerably more.

Parsons was the great early developer of the turbine idea. He built commercial turbines as early as 1886, and began to build really good, well-designed turbines as early as 1895, his work on axial-flow turbines having been interrupted for several years prior to 1894 by patent conditions. By 1903, when the first commercial turbines of the Curtis type appeared, Parsons had made considerable commercial progress and had obtained results considerably superior in economy and in other respects to those obtainable from reciprocating engines. No very large machines had been built and the number in use was small, but all the important features and possibilities of the type had been quite fully developed and were well understood. DeLaval and Rateau had also developed turbines. DeLaval's work was very ingenious and interesting but not very valuable commercially. Rateau's method was correct in principle but best suited to high-speed machines of large capacity, and has not had really good application until recent years.

Parsons' method was original and so was Curtis' idea of directing the jet from a single nozzle so that it impinged successively on two or more rows of blades, giving what he called fractional abstraction of work from the steam velocity. This idea was well adapted to the building of machines of moderate speed of either small or large capacity.

The Parsons type of turbine is subject to certain limitations and difficulties, but, if the leakage can be kept down and the velocity relations are correct, it is susceptible of very good steam economies. Its thrust must be balanced by dummy pistons, which, if not adjusted to close clearance, may involve serious leakage. Steam, in passing through a turbine, increases its volume in some cases as much as 600-fold; consequently there may be difficulty in arranging blade lengths and drum diameters on the same shaft to suit such a wide variation.

The Curtis turbine, as originally built, used in the high-pressure stages only a segment of the wheel. It used large buckets with ample clearances, had very little leakage loss, and was easily designed to suit the highest degrees of vacuum.

In the early applications of the Curtis turbine a very persistent effort was made to induce owners and auxiliary builders to provide apparatus suited to the production of high vacuum, and it is in the use of high vacuum that the turbine has its greatest advantage over the reciprocating engine. The success of these efforts for the use of high vacuum gave very good economies even in stations where the turbines themselves were not of very good efficiency.

The first commercial turbines were built with bucket designs adopted by Mr. Curtis on the strength of such limited experimental data as he had been able to collect. The first 500-kw. machine had two stages with three rows of buckets per stage, and the second commercial machine, a 5000-kw. one started in 1903, had two stages with four rows of buckets per stage.

About the time that the building of these machines was begun the speaker began experimenting to see what could be done with more stages and only two rows of buckets per stage. As a result of these experiments a 2000-kw., 4-stage machine followed the 5000 by only about three or four months, and gave very greatly improved efficiency. This was followed by 5- and 6-stage vertical machines, which finally reached capacities as high as 15,000 kw. at 750 r.p.m. The large machines of this type had efficiencies of 67 per cent under conditions where the best large turbines of recent design would have about 74 per cent. These vertical machines were very practical and simple to build and operate. They had an immense commercial success and greatly advanced the central-station art.

About 1907 the matter of devising means by which higher-speed machines could be made which would be better and less costly was taken up, and this change of speed led to the abandonment of the vertical type, although it might be effectively used today with suitable arrangements for preventing lateral vibrations.

As means and occasion arose for increasing speeds and capacities, the possibility of gain by using wheels with single rows of buckets began to be perceived. The first of such machines retained a two-bucket wheel in the first stage with admission to a part only of the periphery, and many such machines are still made. The best large machines, however, have single-bucket wheels and full peripheral admission in all stages.

The first attempt to use heat in higher temperature ranges than those practicable with steam was in the development of internal-combustion engines, and the greatest advance in this line was the invention of Dr. Diesel, who wrote a book explaining the possibilities of his engine before any were built. The practical details of Diesel engines have been gradually improved and their use has steadily extended, although they have not had any important part in the power-station industry. They are, however, being more and more widely used in ships, where an economical use of oil has very great practical advantage.

The most recent step in the effort for higher economy in making power from fuel, is the speaker's use of mercury vapor to operate turbines in temperature ranges above those which are practicable with steam. In this the heat of the exhaust of the mercury turbine is used to make high-pressure steam, which can be applied in any usual way. An installation of this kind has been operating a good part of the time for the past year at an average load of a little over a thousand kilowatts on the mercury turbine. The operation has been generally very successful and practical, although certain limitations of the mercury boiler have developed, which show that this part must be improved before extensive commercial applications can be undertaken. An effort is being made to bring this Hartford installation to a thoroughly commercial state and the prospect that this will ultimately be accomplished seems very good. In combination with the best steam applications which have so far been developed, this process should give a gain in output from fuel of about 40 per cent over what could be done with the steam alone, and under the conditions of any existing station, the gain should be much more. These figures indicate that the undertaking is worth some effort.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

New Data on Heat Radiation

The following is based on investigations carried out in Düsseldorf at the Heat Research Bureau of the Association of German Iron Makers.

Transfer of heat may occur in any of three ways, namely, by conduction, convection, and radiation. The mechanism of conduction of heat is quite well known, except that there is still uncertainty as to the coefficients of such materials as firebrick at high temperatures.

As regards convection, it is only comparatively recently that sufficiently reliable information has been collected and digested. Among other things, it has been established that the amount of heat transferred is essentially a function of the velocity of the flow of gas and increases as the 0.8 power of the true velocity of flow, but that it is essentially independent of the absolute temperature of the hot body.

But when it comes to the subject of heat radiation there would appear to be still a large amount of uncertainty and plain ignorance, notwithstanding the fact that a large amount of work has already been done on the subject.

Essentially heat and light radiations are both phenomena occurring in the ether and differ only in their wave lengths (at least this is the accepted theory today); violet light has, for example, very short waves and red light much longer waves, while the invisible radiation on the infra-red end has still longer waves, and the waves used in wireless telegraphy are longer yet. In all, the waves vary from X-ray waves of the order of 10^{-6} millimeters to electric waves, which can be miles long.

The Planck law of heat radiation for temperatures from 1000 to 1200 deg. cent. is graphically represented in Fig. 1. The ordinates give the radiation intensity for each wave length and the part of the total radiation energy which belongs to a given wave length as compared with other wave lengths. From this it would appear that the radiation at 1200 deg. cent. consists practically exclusively of wave lengths of from 1 to 15μ, i.e., invisible infra-red radiations, and the effect of light waves, i.e., the region from 0.4μ to 0.8μ, is very slight. At higher temperatures the influence of light waves becomes greater and the peak values of the curves with increase of temperature fall off toward the shorter wave lengths, until finally at the temperature of the sun, say, 6000 deg. cent., light waves constitute the major part of the radiated energy. At the temperatures used in industrial heat engineering, the factor of light radiation may be more or less neglected when considering the total radiation, which means that the technically important radiation is invisible to the eye—with such reservation as will appear further.

The sum of the energy in all the wave lengths of a radiating body gives its total radiation, and this is expressed by the enclosed area of the Planck curve. The total radiation rapidly increases with the temperature as the inspection of the curves will show, and Stefan has shown that it increases with the fourth power of the absolute temperature of the black body (Stefan-Boltzmann law of radiation).

In the majority of cases occurring in particular in engineering, a knowledge of the Stefan-Boltzmann law is sufficient for computing the amount of energy transmitted by radiation. The only trouble is that both the Planck and the Stefan-Boltzmann laws hold good only for the radiation of a *black* surface, i.e., a surface which absorbs all of the energy radiated to it and reflects none of it. Actually there are no such surfaces and the question arises to what extent the radiation laws hold good, and in particular how the behavior of solid and liquid bodies differs from that of gaseous bodies.

Radiation from Surfaces Met with in Practice

As regards solid bodies, we know that the surfaces met with in practice behave differently from the ideal *black* body in that they absorb part of the radiation and reflect part of it. Kirchhoff's law for these bodies states that all such surfaces in each wave length reflect the same part of the radiation of a black body at the same temperature as the part of the radiation in the same wave length which they absorb. As a result of this, all non-black bodies radiate less than black bodies of the same temperature. In practice, radiation coefficients are employed which express the factor of proportionality of the Stefan-Boltzmann law (equal to 4.9 large calories per sq. meter per hr. per 4th power of the temperature in degrees for black radiating bodies), the radiation factor being smaller than the above figure depending on the degree of blackness of the body.

At first glance this seems to be quite simple, but there are two potential dangers which have to be avoided. In the first place, not all technical surfaces radiate "gray," and it is only for gray surfaces that a factor of radiation may be selected in accordance with the Stefan-Boltzmann law, because in the case of gray bodies the Planck curve of radiation, while lying lower than the similar curve for black bodies, is geometrically similar to it in shape. Further, radiation coefficients give the proper solution of the problem only when the radiated surface has at each wave length the same power of absorption, i.e., the surface absorbs the same fraction of the rays notwithstanding the wave length.

As a matter of fact, however, this does not always happen and many surfaces exhibit selective absorption in that they absorb more of rays of certain wave lengths than of other wave lengths. But wherever the absorption is selective, the radiation has to be selective also in accordance with the Kirchhoff law, because the more rays of a certain wave length that are absorbed, the more of them must be radiated. Because of this the radiation of non-gray bodies is selective and the radiation curve of such a non-gray body is not smooth like that shown in Fig. 1 but has depressions which are the wider and deeper the less "gray" the body is. Morever, in the case of selective radiation the Stefan-Boltzmann law, according to which radiation increases with the fourth power of the absolute temperature, holds good no longer, and the radiation factor becomes variable with temperature and must be separately determined experimentally for each temperature.

The second danger in the indiscriminate use of factors of radiation as defined above lies in the fact that even in the case of gray bodies the absorption capacity varies with the temperature, which means that even with them the Stefan-Boltzmann law does not hold good, and the radiation coefficient has to be considered as a function of temperature.

In practice this means that the radiation has to be measured not at some one temperature but over the entire range of temperatures at which particular work is done; no such measurements have been made in the past, and, as a matter of fact, especially at the higher temperatures, they are very difficult to make.

Nevertheless, a certain amount of valuable work along these lines has been done in Germany. V. Polak and E. Schmidt (their work has not yet been published) determined radiation coefficients of certain technically important surfaces, namely, open-hearth-furnace brick and iron at temperatures up to 1150 deg. cent., and found values of the order of 80 per cent and more of the radiation of a black body. They investigated, however, only a few substances and their results need further confirmation.

Observation would tend to indicate that in many cases the coefficients of radiation are smaller. It has been observed, for example, in open-hearth furnaces that in places subject to intense heat transfer temperatures often prevail 100 deg. or more below those of the rest of the furnace. Such great temperature differences would require, with the coefficient of radiation 80 per cent of that of a black body, heat reception through radiation of 100,000 large calories per square meter (36,800 B.t.u. per sq. ft.) per hour and

more, which appears to be impossibly high. These figures indicate the importance of the influence of radiation, especially when it is remembered that the average heat transfer of the entire furnace is only of the order of 60,000 calories per square meter per hour and in boilers 30,000 calories per square meter per hour (22,000 and 11,000 B.t.u. per sq. ft.).

Heat Transfer in Furnaces

One may consider the case of a furnace for heating iron ingots. Such a furnace may be wide and flat so that one may neglect the action of the side walls as compared with the surfaces offered by the roof and hearth. The heating gases flow over the ingots and fill the space between the roof and the ingots. The heat, therefore, in accordance with the respective temperatures, is divided between the roof and the ingots, which constitute really the heating surfaces. The heating action of the gases at certain temperatures is the greater the lower the temperature of the surfaces which they heat. Furthermore, the temperature of the ingots must be lower than the temperature of the roof of the furnace, because the hot ingots are being replaced all the time by cold ones, while the roof is exposed to the action of the gases all the time.

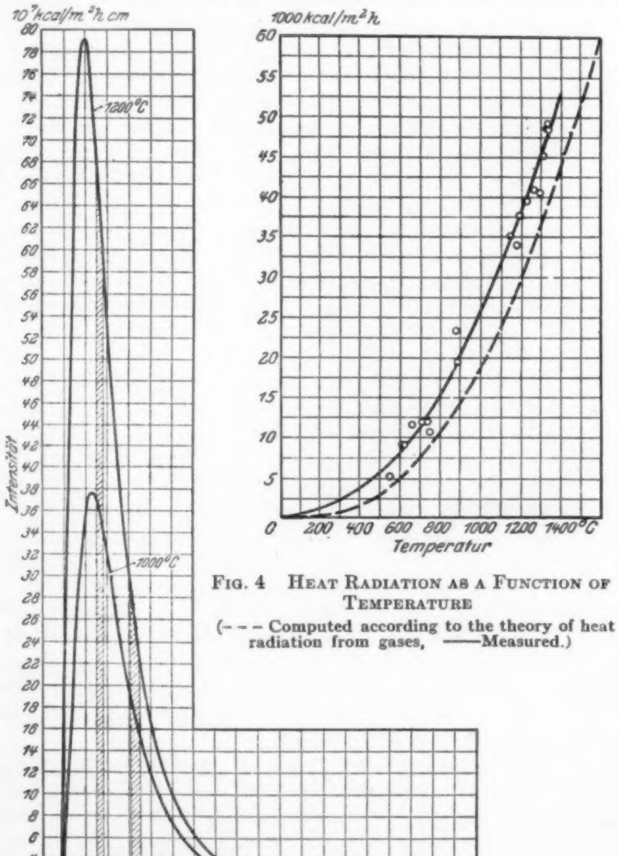


Fig. 4 Heat Radiation as a Function of Temperature

(- - - Computed according to the theory of heat radiation from gases, —— Measured.)

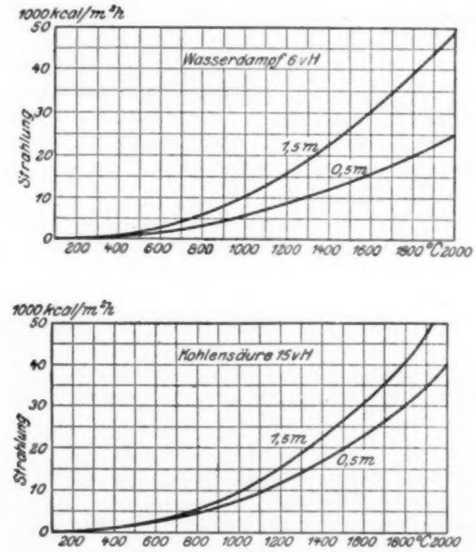
Fig. 1 Intensity of Radiation from a Black Body as a Function of Wave Length

(*Licht* = light; *Wellenlänge* = wave length.)

Since the roof is hotter than the ingots, heat is all the time radiating toward the latter, and since further the heat losses of the roof outward are inconsiderable, nearly the entire heat which the roof receives from the gas is made available by radiation to the ingots. But the roof takes up all the more heat from the gas the lower its own temperature is, and since in this case the temperature of the ingots is the lowest attainable limit, the intermediary heat action of the roof is the greater the less the temperature difference between the ingots and roof, because the less this temperature is, the greater is the temperature difference between the heating gases and roof and the greater the heat transfer from the gases to the roof.

In the ideal case—impossible in practice—of the roof and ingots having the same temperature, one square meter of the roof surface (neglecting external losses and absorption by the gases) would have approximately the same value as a heating surface as one square meter of the ingot surface proper.

If the heating action of the gases remains constant the only factor that determines the difference in temperature between the furnace roof and ingots is the coefficient of radiation, and the greater it is the less must be the temperature difference between roof and ingots in order to permit the radiation of a given amount of heat to the ingots, and hence the stronger is the intermediary heating effect of the roof (it is called intermediary because it takes up the heat from the gases and delivers it to the ingots). Thus, if at a given place the temperature of the ingots is 1000 deg. cent., the inner temperature of the roof must be 1100 deg. cent. provided it radiates as a black body and has to transfer 45,000 large calories per square meter (16,500 B.t.u. per sq. ft.) per hour. If, however, the roof were only 50 per cent black (coefficient of radiation 2.5) it would have to have a temperature of 1175 deg. cent. to permit the same amount of heat transfer by radiation under the same ingot-temperature conditions.



Figs. 2 (above) and 3 (below) Heat Transfer by Radiation from Gases as a Function of Thickness of Layer of Gas and Temperature

(*Strahlung* = radiation; *Wasserdampf 6 vH* = 6 per cent water vapor; *Kohlensäure 15 vH* = 15 per cent carbon dioxide.)

Practically the same conditions apply to the case of brickwork in boilers acted on by flue gases, with the reservation, however, that an exact determination of the influence of radiation of solid bodies on the heat-transfer phenomena in furnaces and boilers will become possible only when the coefficients of radiation have been determined for technically used surfaces at all temperatures.

Radiation of Gases

While the existing knowledge of radiation phenomena in connection with solid bodies is incomplete, the knowledge of radiation from gases is even more defective. Nusselt in 1914, is said to have been the first to initiate tests on the heat radiation from gases, but his tests were limited to conditions obtaining in internal-combustion engines and could not therefore give quantitatively valuable information as to the entirely different processes occurring in industrial furnaces, boilers, etc. The author believes it quite amazing that the importance of radiation from gases has gone unrecognized so long in thermodynamics, which seems to have had focused all its attention on the phenomena of convection to the complete exclusion of everything else.

At the same time, if the existing formula for heat transfer determined from laboratory tests be applied to the flue of a steam boiler or to an industrial furnace, coefficients of heat transfer will be obtained of an order of 7 to 10 large calories per square meter per deg. cent. (1.43 to 2.05 B.t.u. per sq. ft. per deg. fahr.) per hour, while actually the coefficient of heat transfer will vary with the temperature and be of the order of 60 calories per square meter per deg. cent. per

hour, or about eight times the calculated values. The reason for such a large deviation from otherwise correct formulas in the case of boiler flues and industrial furnaces can lie only in the fact that the conditions there existing are different from those assumed in the calculation, and actually the higher level of temperatures and the greater volume of gas flowing constitute the difference from the conditions under which the laboratory formulas were derived. The author believes that here may be seen the influence of radiation from hot gases, because it varies with the temperature and thickness of the gas layers. With the low temperatures and small volumes of gas used in laboratory tests, the influence of radiation from the gas disappears entirely and the heat-transfer phenomena are restricted solely to those due to convection.

Apart from all of these considerations Bansen recognized the technical importance of heat radiation from gases and explained by this latter certain occurrences in industrial furnaces. What was lacking in his time was a proof of the influence of invisible heat radiation from gases, which undoubtedly follows laws entirely different from those governing convection of heat. Then, theoretically, such a proof was produced and it was necessary to start with a theoretical explanation of the conditions obtaining in order to gain an insight into the variables of which heat radiation of gases is a function and of the laws according to which these variables affect the radiation. It was only after such an insight had been gained that one could expect paying results from experimental work.

The theory of heat radiation from gases is based on consideration of thermodynamic equilibrium in a gas-filled black chamber. It can be shown that in such a case in accordance with the two fundamental laws of thermodynamics, the gas absorbs p per cent of the incoming radiation within a region of wave lengths $\Delta\lambda$. It sends out within the same region of wave lengths an amount of radiation which constitutes p per cent of the radiation of a black body within $\Delta\lambda$. In Fig. 1 this band of wave length is indicated by sectioned areas which represent absorption and radiation of carbon dioxide. The foregoing represents nothing but an extended form of the Kirchhoff law of radiation. By using it, it becomes possible to determine the radiation of gases from their absorption spectra, and this, in turn, would indicate that gases which absorb a large part of the spectrum in thin layers radiate most, while gases which do not absorb any appreciable amounts in layers of measurable thickness radiate next to nothing.

Flue gases contain some carbon monoxide and hydrogen, but the chief constituents are nitrogen, oxygen, water vapor, and carbon dioxide. An inspection of their absorption spectra shows that nitrogen and oxygen have no appreciable absorption, while carbon dioxide and water vapor have absorption spectra of comparatively great extent, this in turn indicating that flue gases containing mostly carbon dioxide and water vapor will radiate most; just how much will be shown by a more complete investigation of their absorption spectra.

The most important absorption bands of carbon dioxide are shown in Fig. 1. By comparing the area of the absorption strip with the total area of the curve it would appear that the radiation of a thick layer of carbon dioxide comprises in accordance with the temperature something like 10 per cent of the radiation of a black body. The main difficulty in computing theoretical radiation from a gas lies in the influence of the thickness of the layer of gas, but here also the absorption properties of the gas help most materially. The trouble is that absorption strips of individual gases do not all have the same power of absorption and have apparently variable absorption powers over small regions of wave length. However, if the absorption properties of a gas are studied, it becomes to a certain extent possible to compute the radiation of gaseous bodies of various shapes and magnitudes from the absorption spectra of these gases. Available measurements of absorption show that carbon dioxide as shown by the second strip in a layer of ordinary flue gas 8 cm. (3.14 in.) thick of normal content, i.e., $12^1/_2$ per cent carbon dioxide radiates practically in the same manner as a black body in that strip; on the other hand, however, in the other strip, i.e., the one to the left, similar radiation is attained only in strips several meters thick. It follows therefrom that gases containing carbon dioxide radiate appreciably even in quite thin layers, and as a matter of fact, the area of this second strip at 1200 deg. cent. comprises something like 4 per cent of the area corresponding to a black body, and this at 1200 deg. cent. means a radiation of approximately 9000 calories per square meter (3300 B.t.u. per sq. ft.) per hour when referred to a square meter of surface of the gaseous body. On the other hand, water vapor in layers of such slight thickness does not radiate appreciably.

Since the functional relation between radiation of individual layers is different for different thicknesses of layer, a remarkable fact appears, namely, that the radiation of a gas containing carbon dioxide increases with temperature in each thickness of layer in accordance with a different power, which latter, as a rule, is below 4 (the power in the case of the black body). The same holds good for water vapor, which radiates in thin layers less and in heavy layers more than carbon dioxide.

Figs. 2 and 3 show how the radiation from a gas increases with the temperature and thickness of layer, or what amounts to the same thing, with the temperature and the quantity of a radiating gas in a given gas volume. The remarkable thing about it is that the power according to which increase in radiation occurs with increase of temperature is the higher the greater the thickness of a gas layer. This would explain why, as has been found in practice, it is advisable in the hottest parts of the furnace to make the roof higher than in the cooler parts. Furthermore, since the radiation from gas obeys laws different from those which control radiation from solid bodies, it is not at all surprising that in the past it has been found impossible to handle problems of heat transfer at temperatures above 400 deg. cent. with the processes then known.

According to the present theory—which contains, however, still many uncertain figures—it would appear that radiation in furnaces and boilers may attain the very extraordinary value of 50,000 calories per square meter (18,400 B.t.u. per sq. ft.) per hour and more. At temperatures of 300 deg. cent. and gas layers of slight thickness such as those in the flues of Lancashire boilers 100 mm. (4 in.) in diameter, radiation is practically negligible as compared with convection, but under the conditions prevailing in open-hearth furnaces convection accounts for only something like 10 per cent of the total heat transfer.

There has been a considerable amount of work done in various German steel mills to obtain experimental confirmation of the main facts in the theory of heat radiation. The most important data are said to be contained in the as yet unpublished investigation of Lent and Thomas, who carried out their work at the Rhine Steel Works on a blast-furnace flue of 1.3 meters (51 in.) diameter in a special section about 20 meters (65 ft.) long. The data obtained in their measurements are shown in Fig. 4. From this it would appear, as has been shown theoretically, that the radiation actually observed is larger than the radiation precomputed. At Bansen's request Heilengenstädt carried out investigations at the Friederich Alfred Mill in Rheinhausen on heat transfer at temperatures up to 1000 deg. cent. in a pipe about 100 meters in diameter [The figure "100 meters" is taken from the original article and no information is available to show whether it is correct, or if not, what was meant—EDITOR.], and found that in the case of gases containing carbon dioxide there was a heat transfer greater than with air and in quantitative agreement with theory. Qualitative confirmation of the influence of gas radiation is also supplied by Goebel's observations at the Julien Mill in Upper Silesia, where it was found that the coefficient of heat transfer between the gas and checkerwork in the regenerator of an open-hearth furnace was materially greater than the coefficient of heat transfer between air and checkerwork; the same condition was established by Lent at the Rhine Steel Works.

All of this would indicate that it may be safely assumed that heat radiation from gases exerts a material influence on the performance of furnaces and that it becomes necessary to consider heat transfer from gases as consisting of two components, of which one follows the law of convection and the other the law of radiation.

The tests carried out by Lent and Thomas dealt with the influence of additions of benzol to a blast-furnace-gas flame, these additions being so regulated as to make the flame strongly illuminating without becoming hotter. It was found that in this case the radiation from the flame increased almost four-fold and approached radiation from a black body of the same temperature. This would indicate that illuminating flames with incandescent particles of carbon floating in them radiate more powerfully than non-illuminating flames. On the other hand, the former, often as a result of in-

complete combustion, gave lower temperatures than the latter. Nevertheless, these tests would indicate that the values of heat radiation from gases obtained theoretically may in the majority of cases be considered as only minimum values and that higher values may be obtained from illuminating flames.

Further Investigations Necessary

The subject is of great importance and further investigation is necessary. The author points out that such investigations have been planned at the Institute of Physical Sciences of the University of Bon and at the Research Institute of Heat Insulation in Munich.

Another question which the author raises leads to a rather unexpected conclusion. At first glance it would appear that since the knowledge of the great influence of radiation from gases is practically new, furnaces which have been designed and built in the ignorance of this factor would be ready for the scrap heap.

Actually, however, it seems that present furnaces, while built without a clear understanding of the underlying theory of the phenomena of heat transfer that take place in them, happen to be so proportioned that they work at a good efficiency and satisfy the requirements imposed by the newly discovered theory of heat radiation from gases. In other words, the furnace designers of the past builded better than the new. (Dr. of Engrg. Alfred Schack in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 58, no. 39, Sept. 27, 1924, pp. 1017–1020, 4 figs., *teA*)

Short Abstracts of the Month

ENGINEERING MATERIALS (See also Metallurgy: Steel at Highest Working Temperatures; Testing and Measurements: Monel Metal)

Bronze Sparkless Tools

Steel and iron tools cannot be used in powder buildings because of the danger from sparks. At the works of the Hercules Powder Company tools are now used made of a special bronze developed by the plant blacksmith, Otto Riepling.

These tools are said to be both hard and safe, and all of the powder buildings at the Hercules plant will soon be equipped with Riepling tools, such as hammers, pliers, and shovels to handle nitrate of ammonia. These tools are said to be highly acid-resisting. The metal is of such a character that a knife has been made of it with a keen razor edge. The composition of the material is not stated. (*The Hercules Mixer*, vol. 5, no. 10, October, 1924, p. 215, 1 fig., *d*)

Lautal: A New Light Alloy

Lautal is the most recent of the heat-treatable aluminum alloys and is made by the United Aluminum Works, Lautawerk, Germany. It consists of aluminum—not more than 93 per cent—copper, and silicon, with iron present only as an impurity introduced by the constituent metals.

The treatment which the alloy undergoes consists of a combination of working and heat treatment, but no details as to either are presented.

As regards the properties of the alloy, it is stated that it has a tensile strength of 38 to 43 kg. per sq. mm. (54,000 to 61,000 lb. per sq. in.) with an elongation of 18 to 23 per cent. After treatment its tensile strength increases to 60 kg. per sq. mm. (85,000 lb. per sq. in.), but elongation falls off to about 4 per cent. The elastic limit of normal alloys, that is, previous to the special treatment, is from 30 to 33 kg. per sq. mm. (43,000 to 47,000 lb. per sq. in.)

The Brinell hardness number of the alloy in its normal state is about 92, but increases after treatment.

The main advantage of the alloy is seen in its ability to resist general corrosion influence and, in particular, sea-water corrosion. It is stated, however, that the manufacture of the alloy requires a high grade of care and skill. Articles should be made of the alloy only after it has undergone proper treatment, and it is further stated that the alloy is not subject to aging. The alloy can be machined, forged, and drawn. (Dr. V. Fuss in a paper presented before the German Metallurgical Society in Berlin, March, 1924, and in Stuttgart, June, 1924. Abstracted through *Zeitschift für Metallkunde*, vol. 16, no. 9, Sept., 1924, p. 343, *d*)

FUELS AND FIRING

The Cleaning of Coal by the Conklin Flotation Process

The flotation medium employed in the process developed by H. R. Conklin, of Joplin, Mo., is a mixture of water and very finely ground rock, ground to such a fineness that at low dilutions the particles will remain substantially in a quiescent suspension without agitation. The pulp must be practically free from colloids, as otherwise it would be too viscous to permit the free settlement of the rock through it. Magnetite ore ground to pass a 200-mesh screen makes a very satisfactory material for the pulp, dilutions having a ratio of weight of water to weight of solids of between 0.4 to 1 and 0.1 to 1 giving the best results.

The original article contains data on the apparatus used, which is of experimental character only, and the flow sheet of the test plant, as well as some data of the tests in which the Conklin plant was operated in competition with jigs working on exactly the same feed. The following average results were obtained:

	Conklin plant	Jigs
Long tons treated per hour	22.29	12.53
Per cent slate in washed coal	1.97	3.72
Per cent bone in washed coal	3.51	1.96
Per cent recovery of coal in feed	99.31	99.38
Per cent removal of slate in feed	93.12	86.39
Per cent coal in refuse	1.97	2.03
Overall efficiency of separation, per cent	91.21	85.66

Overall efficiency is based on the percentage of coal and bone in the feed that is recovered and the percentage of slate in the feed that is removed, the calculation being percentage of coal and bone recovered divided by percentage of slate removed.

The slightly lower percentage recovery of coal in feed for the Conklin process is more than justified by the higher grade of product produced.

The actual loss of magnetite during the test period averaged 35.43 lb. per ton of coal fed to the plant. It is estimated that about 16 lb. out of the 35.43 lb. was lost because of the poor plant construction, and could have been avoided. The remaining 19.43 lb. represents the necessary magnetite consumption.

The cost of magnetite laid down at the breaker will vary widely, depending on the location of the breaker with relation to the source of the magnetite supply, and an even greater factor will be the capacity of the breaker. If large quantities of pulp are required, the cost can be reduced materially by installing a small grinding plant at the breaker. It is estimated that the cost of the magnetite ready for use will vary between \$3 and \$7 per ton, which figures a cost of 3 to 7 cents per ton of coal treated, based on a loss of 19.43 lb. of magnetite.

The average quantity of pulp circulated was 140 lb. per ton of coal treated. This figure represents the quantity of material that must be reclassified, rethickened, and returned to the circuit.

The water consumption in the Conklin test averaged 184 gal. per ton of coal treated as against about 125 gal. for the jigs. This figure could be greatly reduced by reusing a portion of the Dorr thickener overflow, all of which was sent to waste. (*Fuel in Science and Practice*, vol. 3, no. 11, Nov., 1924, pp. 400–403, 2 figs., *d*)

HEATING

New Process of Plant Heating

In connection with the discussion of the influence of high-pressure steam on the development of industrial power plants, the author mentions what he refers to as a new process of heating which he claims permits increasing the efficiency of the steam-heating plant without lowering the heating temperature.

If in a heating plant it is desired to have a heating temperature of t_1 which corresponds to a steam pressure p_1, this latter would be the back pressure of the steam prime mover, the exhaust of which is used for heating purposes. If heating is effected by water of the same temperature, t_1, which is cooled to t_2 by going through the

heating plant, then the water has to be heated from t_2 to t_1 by the back-pressure steam. This may be done in stages in order that the working steam be utilized down to a pressure much lower than p_1.

Schematically such a plant is shown in Fig. 1, where *a* is the warm-water tank where the water circulating in a closed circuit is heated by the exhaust steam from t_2 to t_1. The heating apparatus is set in between the incoming and the outgoing circulation, the pump *b* circulating the water. The heating coils *c*, *d*, and *e* are connected to the various stages of a multi-stage back-pressure

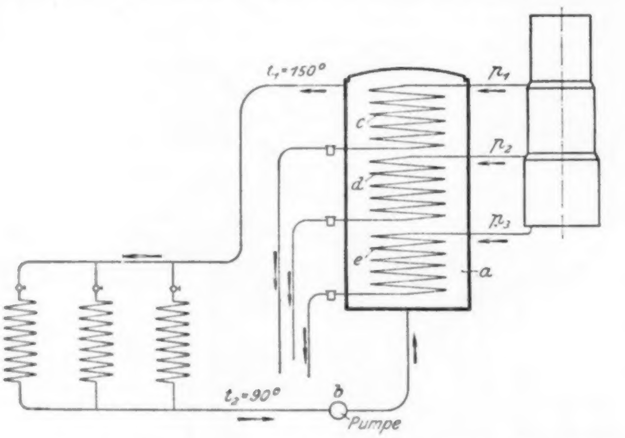


FIG. 1 SCHEMATIC LAYOUT OF A MULTI-STAGE BACK-PRESSURE STEAM PRIME MOVER WITH HOT WATER AS THE HEATING MEDIUM

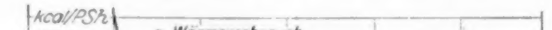


FIG. 2 HEAT CONSUMPTION OF THE PRIME MOVER SHOWN IN FIG. 1 AS A FUNCTION OF PRESSURE

(*kcal/PSh.* = large calories per horsepower-hour; *vH* = per cent; *Druck/p* = pressure *p*; *a*, heat consumption; *b*, heat conveyed to the water; *c*, equivalent heat consumption in a plant working condensing; *d*, heat saving as compared with plant working condensing; *e*, heat saving as compared with a single-stage back-pressure steam-heating plant.)

prime mover and heat the water to temperatures corresponding to the respective pressures of steam in the various stages, doing it gradually from t_2 to t_1. If we assume that t_1 is 150 deg. cent. (302 deg. fahr.) and the water is cooled by going through the radiators to 90 deg. cent. (194 deg. fahr.), 60 deg. cent. (108 deg. fahr.) of heating range becomes necessary. If each stage gives 20 deg. cent. (36 deg. fahr.), then the lowest coil must be heated to 110 deg. (230 deg. fahr.), the second to 130 deg. (266 deg. fahr.), and the third to 150 deg. If the pressure in each of these heating coils is so selected that the corresponding temperature is 5 deg. cent. (9 deg. fahr.) higher than the water temperature at delivery, we have a three-stage machine with end pressures p_1 5.5 atmos. abs., p_2 3.2 atmos. abs., and p_3 1.7 atmos. abs.

The heat consumption of such a three-stage prime mover which operates in every stage with superheated steam to start with and saturated steam at the end of the expansion is shown in Fig. 2 by the curve *a*, and the heat gained by the water by the line *b*. If now on the line *b* the heat consumption of a pure condensing machine be plotted, the line *c* is obtained and the cross-hatched area indicates the saving in heat effected by the use of the back-pressure steam. The line *d* indicates the percentage saving of heat as a function of the initial pressure. (Chr. Eberle, Darmstatt, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, no. 39, Sept. 27, 1924, complete article pp. 1009–1016, and the present abstract pp. 1012–1013, 17 figs., *gdA*)

INTERNAL-COMBUSTION ENGINEERING

The Lincoln Sleeve-Valve Engine

THE characteristic feature of this engine is the exceptionally short travel of the operating sleeve. There are really two sleeves, of which one runs the full length of the cylinders and is between the piston and the water jacket, while the other is a very short one and is located in the head. Both sleeves, Fig. 3, have ports which register together and with the exhaust port on the exhaust stroke and with the inlet port during the suction stroke.

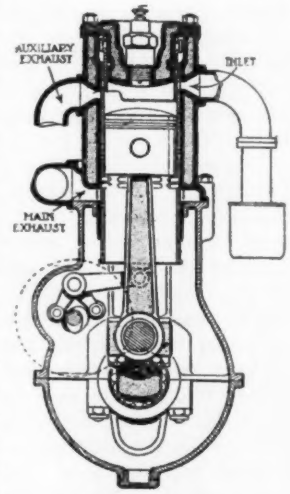


FIG. 3 LINCOLN SLEEVE-VALVE ENGINE (SLEEVE POSITION ON THE COMPRESSION STROKE)

Auxiliary exhaust ports are cut in the long sleeve and register with the exhaust passage at the base of the cylinders so that they are uncovered by the piston at the bottom of the working stroke. Only a very short movement is necessary for both sleeves. The sleeves are operated by a cam-and-lever movement, the lever being connected to the longer sleeve at its base and to the upper lever by means of a push-and-pull rod, the lever motion in both cases being arranged so that one cam moves the sleeve upward and another downward. This is contrary to the more usual practice of operating sleeve valves by an eccentric drive. The head is carried down below the level of the sleeves as this might result in trapping the water. A siphon pipe is provided from the jacket round the head to the jacket round the cylinder, by which means one tap is sufficient to withdraw all the water when necessary in cold weather. Ball races are used for the crankshaft and the cylinder is deeply spigotted in the crankcase. (*The Autocar*, vol. 53, no. 1516, Nov. 7, 1924, p. 958, 1 fig., *d*)

Development of Gas and Oil Turbines

Two articles dealing principally with the Holzwarth type of turbine. (Compare MECHANICAL ENGINEERING, vol. 42, p. 292; vol. 44, pp. 187 and 453.) The building of these engines is now in the hands of Thyssen & Co., Mulheim, Germany.

The original articles describe the design of the turbine in general. This part is not abstracted here as it does not materially differ from previous publications.

For the 5000-kw. unit the wheel has a diameter of 9 ft. and weighs 12 tons. Compression pressures in the explosion chambers are about 40 to 50 lb. above atmosphere and with a temperature at about 200 deg. fahr. While the mixture is eddying it is ignited by high-tension plugs. The whole mixture is burned before the nozzle valve opens, the combustion of the amount of gas admitted producing a pressure of about 250 lb. above atmosphere, at a temperature of about 2500 deg. fahr. At the moment of maximum pressure the nozzle valve is opened rapidly to its full extent by means of the initial explosion pressure and expansion begins. The gases expand

through nozzles of the de Laval type to the exhaust pressure, slightly above the atmosphere, and drop in temperature to 1250 deg. at the end of the nozzle. The explosion and expansion cycle and the impulse imparted to the wheel last only about one-fifth of a second.

As soon as the expansion is finished, air is scavenged through the explosion chamber, nozzle valves, and nozzle, sweeping out of the chamber and ducts any lingering gases and thereby cooling all the parts. This scavenging air, mixing with the expanded products of combustion in the turbine wheel chamber, reduces its temperature to about 800 deg. This is the highest temperature to which the thinnest parts of the running wheel vanes are submitted, while its mean temperature is somewhat lower, owing to heat being radiated to the water-cooled walls of the wheel chamber. This scavenging lasts from $^1/_2$ to 1 sec. The nozzle valves are then closed and the gas and compressed-air inlet valves opened for a new charge.

The question of the action of high-temperature gases impinging on the turbine wheel vanes has been solved by Holzwarth through the application of intermittent action, the hot gases acting a relatively short time, after which cooler gases and then cold air come in contact with the vanes. This establishes the main difference between the action of the Holzwarth gas turbine and of a steam turbine. In the steam the acting fluid impinges upon the turbine blades continuously and with uniform velocity; in the gas turbine the combustion gases are projected from several nozzles through the turbine wheel blades like machine-gun fire.

From the present articles it does not appear clearly what the progress of the development has been since the building of the 5000-kw. turbine in 1920.

The second article gives data of tests on a 300-kw. and a 700-kw. turbine. It is claimed that tests with the latter, which is the latest, showed an efficiency at the driving shaft of 17.2 per cent. Among other things are mentioned recent calculations made by Dr. Ulrich Meininghaus, of St. Paul, Minn. Calculations are given as to the economic efficiency of gas-turbine generators of 500 kw. each as compared with gas-engine generators of 3500 kw. each and steam-turbine generators of 5000 kw. each, when installed in a plant for a total output of 25,000 kw. From this it appears that the total cost per 1000 kw-hr. is \$5.25 for a gas-engine plant, \$4.46 for a gas-turbine plant, and \$5.21 for a steam-turbine plant, while the installation cost per kilowatt for a gas turbine is about half that of a gas-engine plant and 0.6 that of a steam-turbine plant. (*The Iron Age*, vol. 114, nos. 21 and 22, Nov. 20 and 27, 1924, pp. 1329–1333 and 1407–1409, 14 figs., *d*)

Two-Cycle Double-Acting M.A.N. Diesel Engine

Of late several attempts have been made by large companies to introduce two-cycle double-acting Diesel engines, for example, by the Sulzer Company in Europe and the Bethlehem Steel Company in this country. Because of this, information as to the engines built by the Augsburg-Nuremberg Machine Works (M.A.N.) is of interest.

This engine is said to develop 1.9 times as much power as a single-acting engine of the same dimensions. Contrary to usual practice, exhaust and scavenging are effected through ports located on the same side of the cylinder and extending over about half the circumference. The exhaust ports are uncovered by the piston a little before the scavenging ports, so that the pressure is comparatively low at the time when the scavenging air enters the cylinder.

The first machine was built from parts of a 12,000-hp. engine which was previously built by way of experiment in the Nuremberg shops, and the present article deals primarily with this early design, of interest because of its size. The four base pieces carry the cross-piece supporting the cylinder which is kept in place by forged steel bars stressed in tension. In the cylinder are located double-wall cylindrical chambers which form an interior cooling jacket, the result of which is that the exterior jacket of the cylinder does not have to be cooled at all. Stays inside the jacket form baffles which direct the circulation of water and insure a good cooling.

The working piston carries a cooling chamber on the surfaces where combustion takes place. The circulating water enters and leaves by the hollow piston rod and telescopic tubes so located that no water can escape into the crankcase. In the machine as built and illustrated in Fig. 4, the injection air is furnished by a two-cylinder compressor direct-connected to the engine, while a three-cylinder reciprocating-type blower provides scavenging air.

This machine was put to work on December 22, 1923, and has given full satisfaction in its operation as well as developing the expected power. After the first run of 120 hr. at 85 r.p.m. and full load, the piston was dismounted and inspected; as no trouble was discovered, the machine was reërected in the same manner as before, but the speed was increased to 100 r.p.m. A test of 121 hr. was run, the data of which are given in a table in the original article. After the machine had run for about 500 hr. altogether, the speed was raised again, this time to 110 r.p.m., under full load,

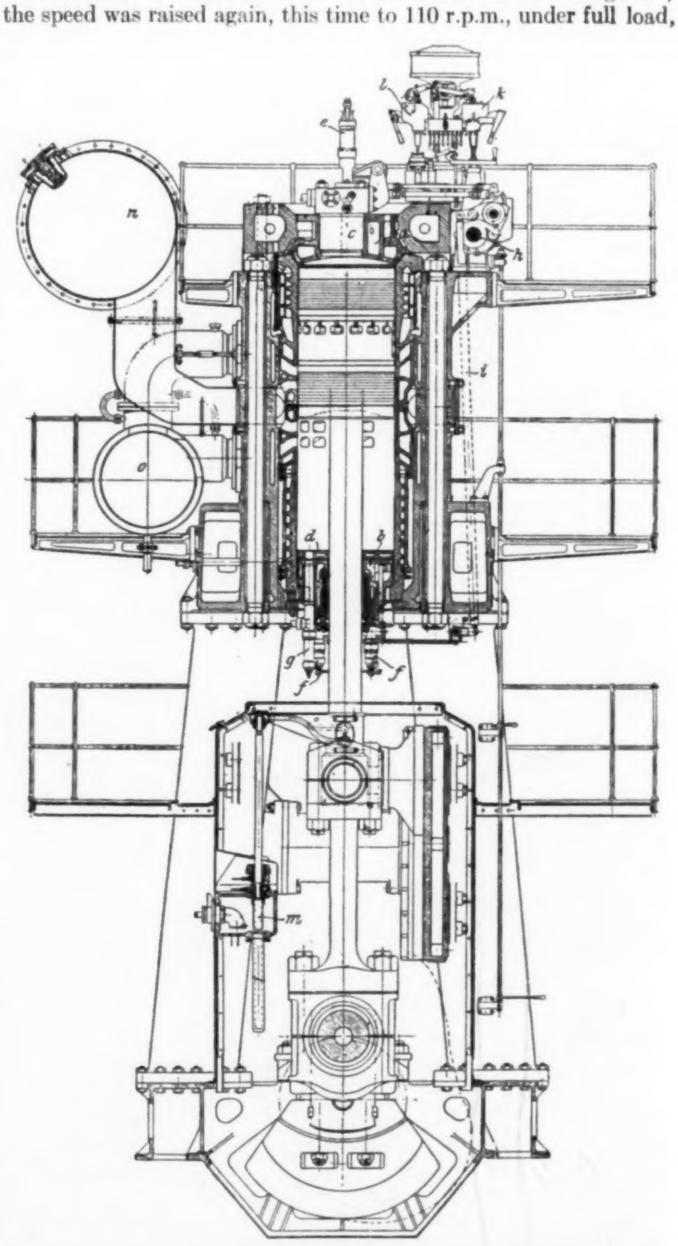


Fig. 4 M.A.N. Two-Cycle Double-Acting Single-Cylinder Diesel Engine

(*a*, upper cylinder head; *b*, lower cylinder head; *c*, valve seats; *d*, cooling jacket of lower cylinder head; *e*, upper middle; *f*, lower middle; *g*, safety valve; *h*, camshaft; *k*, main fuel pump; *l*, starting pump; *m*, telescopic pipe for water circulation; *n*, scavenging-air inlet; *o*, gas exhaust.)

and a good combustion was obtained. A table in the original article gives the results of tests at various speeds, the average combustion being about 185 gr. (0.407 lb.) per effective hp-hr., which is substantially equivalent to the fuel combustion of a four-cycle motor. It should be remembered, however, that this figure was obtained from a single-cylinder engine and that better results may be expected from a multi-cylinder engine.

As regards the future, it is stated that airless injection will be employed. A nine-cylinder engine to deliver 11,000 hp. is now being designed. (*Bulletin Technique de Bureau Veritas*, vol. 6, no. 10, October, 1924, pp. 185–187, 2 figs., *d*)

The Significance of Exhaust Temperature

Data of an investigation carried out on a Carels Diesel engine installed at Oxford, England. While the engine was rated at 600 b.hp., 360 kw. was adopted as its safe maximum load. After the installation trouble developed, namely, high fuel consumption. About 0.53 lb. per b.hp-hr. was the best result obtainable, and that at well below full load. The exhaust was very dirty and the indicator diagram different from the usual character.

The first effort to meet this difficulty was by slightly changing the design of the piston. The indicator card, however, remained as distorted as before. It was therefore decided not to use the indicator card for tuning up, except for the rudimentary purpose of adjusting firing point and compression. It was decided instead to be guided largely by exhaust temperature. Quite early in the experiments it was established that there was a straight-line law connecting exhaust temperature and mean indicated pressure. This is shown in Fig. 5, where the mean indicated pressure is calculated from the indicator card and is the area of the power card plus the area of the rather large loop which was obtained with the fuel cut off. This loop area was constant for all cylinders and for a very wide range of speed, proving that it was not due to cylinder leakage. This was followed by a series of experiments, one factor only at a time being altered. In all 27 variations were investigated, and the data are given in the original article.

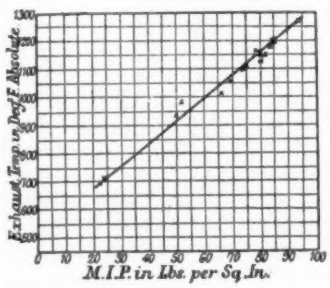


Fig. 5 Relation between Exhaust Temperature and Mean Indicated Pressure in a Diesel Engine on the Test Block

After securing consistent results with normal cylinder pressure, viz., 38–39 atmospheres at full load with 65–70 atmospheres blast pressure, the effect of retarding the timing was tried. It was found that by reducing the peak of the diagram the exhaust temperature was increased. The actual figures are given as follows:

Fuel admission, degrees before top dead center	M.i.p., lb. per sq. in.	Blast pressure, atmos.	Exhaust temp., deg. fahr.
Normal 9 deg.	80.1	65	675
Normal 8 deg.	79.2	65	720
Normal 7 deg.	78.5	65	710

Provided the area of the holes in the rings was well in excess of the minimum area of the flame plate, i.e., 8 to 10 times, there was no difference in exhaust temperature with large variations of this factor.

The official trials of this engine, in the finish, were perfectly normal.

The original article gives a table showing a comparison of the test-bed figures and service results obtained by a customer to whom the engine was ultimately delivered. Among other things this table shows that when operating on tar oil the exhaust temperature appears rather lower than with ordinary fuel oil. This suggests that exhaust temperature is also a function of viscosity of fuel, tar oil being very much thinner than normal fuel oil. (P. H. Smith in a paper read before the Diesel Engine Users' Association, Oct. 3, 1924, abstracted through *Engineering*, vol. 118, no. 3068, Oct. 17, 1924, pp. 544–547, 3 figs., *e*)

MACHINE DESIGN AND PARTS

Synchro-Balance Driving Gear

Description of a device brought out recently in England, one of the purposes of which is to secure a perfect balance of the reciprocating parts of engines having four cylinders or cylinders in multiples of four. In this case the angularity of the connecting rods is reduced to a negligible minimum, thus causing the two outer pistons to be moving at all times at exactly the same speed as the two inside ones, and resulting in a balance.

From Fig. 6 it would appear that the motion of the parts oscillating on the journals are opposite and equal, and that there is no side thrust on the pistons and consequently nothing to make them slap over at the ends of their stroke.

The crankshaft, being arranged rather at the side of the cylinders than beneath them, is very accessible and may be partitioned off from the portion of the case lying immediately beneath the cylinders, thus enabling all cylinder drainings, carbon, etc. to be kept out of the crankshaft lubricating oil.

Very short connecting rods can be used, allowing the design of the engine to be about half the height of the conventional type without increasing either the length or the width, which may be of value for airplane engines. Owing to the elimination of the angularity of the connecting rod the slipper guide on vertical Diesel engines can be dispensed with, thus further reducing the height which is such a drawback in these engines. (*Gas and Oil Power*, vol. 20, no. 230, Nov. 6, 1924, pp. 27–28, 3 figs., *d*)

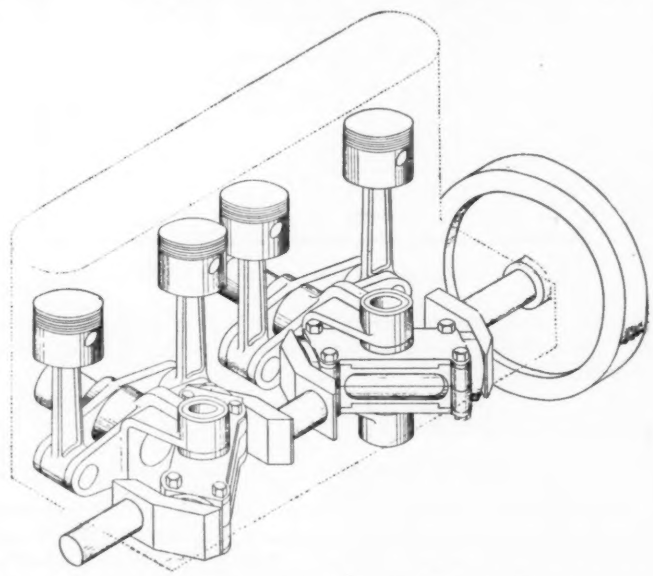


Fig. 6 Isometric View of Synchro-Balance Driving Gear Applied to a 4-Cylinder Vertical Engine

The Bartlett Angular Transmission

This transmission has been used for several years in such service as, for example, a substitute for a pair of miter gears on an automatic wire-forming machine. It can be used for right-angle transmission, but is also applicable to any shaft angle from 0 to about 120 deg. If the shafts are swiveled as in Fig. 7 a complete angular sweep of 180 deg. or 90 deg. in either direction is possible; and by adding a ring and a second swivel pin a universal joint of very great angular sweep may be produced. Such a universal joint has also the property of maintaining a uniform angular velocity ratio of 1 to 1 between the driving and the driven shafts.

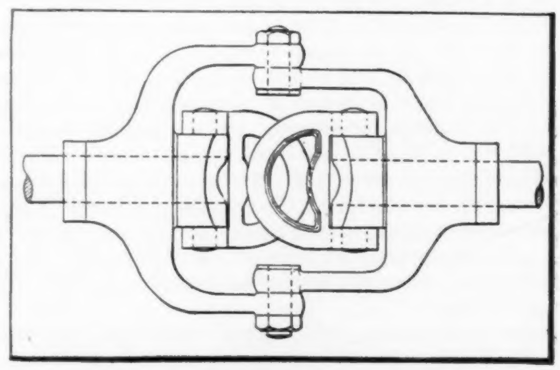


Fig. 7 Transmission with Swiveled Ends

From Fig. 8 it is possible to obtain a good idea of the construction and action of the parts when the transmission is used for a right-angle drive. The two hubs A are keyed to the shaft ends. Each hub carries two hardened steel pins D, over which the driving

members B and C are free to turn through an angle of somewhat more than 45 deg. on each side of the shaft axis. The member C is of cast iron, semi-steel, or bronze, and is slotted to provide a sliding fit for the member B, which is of steel with the working surface hardened and ground. The openings in the semicircular parts are for the purpose of reducing the weight, and the extra

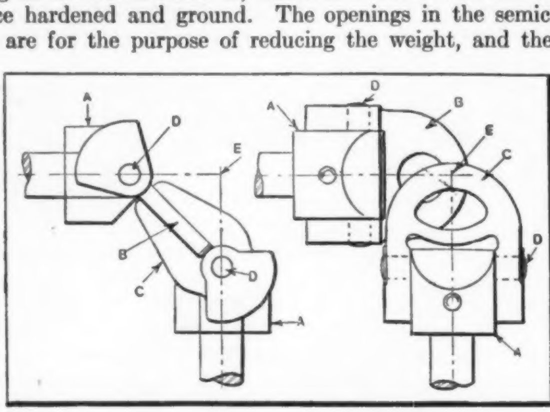


FIG. 8 TRANSMISSION USED FOR RIGHT-ANGLE DRIVE

metal on the opposite side of the pins acts as a counterbalance, but is not needed except for high speeds. (G. M. B. in *Machinery* (London), vol. 25, no. 631, Oct. 30, 1924, pp. 137–138, 5 figs., *d*)

MACHINE SHOP

Jigs for Tool Setting—"Greased Air"

DESCRIPTION of some of the methods employed by the Worthington Pump and Machinery Corporation at the Snow-Holley Works, Buffalo, N. Y., on repetition work, such as planing of bosses on three sides of horizontal gas-engine cylinders, the bosses being for the mounting of valve gages and camshaft hangers.

Instead of using blueprints, service gages, and scales for setting up and checking, the workman first bores the cylinder to finished size and faces the ends. He then attaches to it two jigs, one at each end, bolting them on by through bolts. These jigs are so made that they fit into the cylinder bore by pads machined on one side to cylinder diameter. One edge of each jig is made to serve instead of feet to support the cylinder. The other three sides are exactly to the required size for the bosses when machined.

By setting his tools to the edge of the jig the operator is assured of planing the cylinder to desired dimensions. The same principle is used in cross-planing horizontal engine beds, and in the case of a certain large bed the casting for which weighed 225,000 lb., a 36-in. planer was mounted on the casting with the tool strapped to the planer table to plane the bearing boxes.

An unusual method of clearing chips and lubricating the cutter is employed in this shop on deep-hole drilling. Work is carried in a long-bed lathe spindle and steady rest. The drill is made of a shaft in which a chip clearance groove has been milled and along one side of which is carried a tube for coolant and lubricant to the cutter, which is inserted in the front end of the bar. The bar is mounted in a special rest on the lathe carriage and has at its rear end a connection for attaching a lubricator and air hose. Chips are blown out through the clearance groove by compressed air, which picks up oil dripping from an ordinary drip lubricator. The combination forms a "greased air" which lubricates the drill, cools it, and removes chips.

To assure perfect crank webs without chance of pipes or other defects, the forged webs after machining on the outside have the shaft and pin fits trepanned in a horizontal boring machine. A jig is employed which has the two holes laid out at proper centers and bushed with hardened bushings. This jig is placed with its edges parallel with the edges of the web and its ends are provided with set screws in lugs to hold it in place on the forging. The trepanning tool has three bits of high-speed steel set in a mild-steel shell. Back of each bit is a duct for coolant, leading through the shell walls to a stuffing box close to the machine spindle. To this stuffing box is attached a pipe leading from a pump which generates pressure for the coolant. (*The Iron Age*, vol. 114, no. 21, Nov. 20, 1924, pp. 1327–1328, 3 figs., *d*)

METALLURGY (See also Engineering Materials: Lautal)

Steels at Highest Working Temperatures

THE steels tested were carbon steels with contents of 0.05, 0.70, and 1.40 per cent carbon,[1] special steels containing one alloying element—silicon, chromium, or tungsten, and complex steels, i.e., chrome-nickel and high-speed tool steel.

The conclusions which the author arrives at are as follows:

1 With increase in temperature the tensile strength and "ultimate stress" decrease, but only disappear at the melting point. The proportional elastic limit likewise decreases, and there is a marked increase in the tendency to flow under slowly applied loads.

2 Similarly the elongation increases with temperature in all the steels tested except that containing 2 per cent silicon and the 3-to-1 nickel-chromium forging steel. In these cases minimum or low elongation values are shown in the neighborhood of 1000 deg. cent.

3 In commercial carbon steels the reduction of area increases generally with temperature, but the changes are very small above 950 deg. cent. and not of much practical importance. In the alloy steels tested the changes encountered with temperature vary widely with the composition of the steel; however, a marked increase in reduction of area up to 700 or 800 deg. cent. is observed in all five alloy steels; at higher temperatures only a small increase, similar to that in carbon steels, is shown in the 2 per cent chromium and 3 per cent tungsten steels, while a sharp decrease and minimum values are found in the neighborhood of 1000 deg. cent. for the (3-to-1) nickel-chromium and 2 per cent silicon steels. This range of "reduced malleability," which is to be avoided in hot working these steels, is followed by a rapid increase and high values of reduction of area at 1200 deg. cent. (P. Eyermann, Consulting Engineer, Vienna, Austria, in *The Iron Age*, vol. 114, no. 20, Nov. 13, 1924, pp. 1270–1273, 8 figs., *e*)

Slag Inclusions in Relation to Fatigue

PART of a symposium of papers on fluxes and slags in metal welding and working. This symposium was divided into two parts: (1) Melting and smelting, and (2) slag inclusions, welding, and soldering.

The author believes that the general view based on practical experience that slag inclusions in an otherwise sound metal tend to promote fatigue, is supported by experimental research but appears to require further investigation. It is possible that different slags have widely different effects, and also that the effect of a given slag may depend on how the stress varies—whether it is a pulsating or an alternating stress that reverses its direction.

The author classifies briefly the experimental evidence indicating the harmful effect of slag, and points out that the influence of slag inclusions varies considerably in different methods of testing. He also points out that slags may influence the fatigue strength of metals in at least three distinct ways; namely, chemically (not generally important except in certain circumstances); expansively, and elastically. These two latter ways are investigated mathematically in considerable detail. The author comes to the conclusion that the effect of the slag-filled opening is always less than that of the empty opening. He also points out that the influence of the slag varies with its form and may be great where the inclusion is irregular with sharp projections. The influence of slag depends also on the character of the stress variations during the cycle of loading. Ductile metals subjected to stresses that pulsate without change in direction may be comparatively immune from the ill effects of slag inclusions, provided that these are small in comparison with the sections or parts. (Prof. D. P. Haigh in *Transactions of the Faraday Society*, vol. 20, pt. 1, no. 58, Aug., 1924, pp. 153–157 and discussion, pp. 157–158, *t*)

MOTOR-CAR ENGINEERING

Rear-Tire Slip Tests at Mason Laboratory

DATA of an investigation of the amount of slip of the rear tires in ordinary road driving which has been carried on at Mason Laboratory, Yale University. The tests dealt with two forms

[1] Figure taken from the original article.—EDITOR.

of slip, namely, a slow displacement or creep due to elasticity of the rubber similar to the creep of a leather belt on its pulley, and also an abrupt jump when the tire momentarily leaves the road. A third form of slip is possible, namely, a spin, or skid, when the tire loses its traction on a slippery road, but this has not been investigated.

Some standard is required of the slip of the driving tires. Probably the most convenient standard is the front wheels when not equipped with front-wheel brakes. A reference standard can be determined by driving the car at low uniform speed on the level, or a very slight down grade, and noting the comparative revolutions of front and rear wheels. During the standard run the rear wheels will be exerting but slight traction, hence their slippage may fairly be assumed to be negligible. Any departure in ratio of revolutions of front and rear wheels from the standard may be properly charged to slip of the rear tires.

In these tests a Ford sedan was used with Veeder counters on all four wheels reading to one-fifth revolution and at three different tire inflations.

The greatest slip occurred on upgrade, speed 30, inflation 55, when the rear tires gained 11.7 revolutions per thousand revolutions of front tires, or 1.17 per cent. It appears, therefore, that the rear-tire slip of a light car with cord tires may be as great as one per cent for ordinary driving.

The effect of low air pressure on tire slip is well shown by the runs at inflations 45 and 35, where the gain in revolutions was only 10.8 and 8.6, respectively, as compared with 11.7 at the higher pressure. The difference, amounting to 25 per cent, is probably due to lessened rebounding of the tires with lower air pressure.

The slip on the down-hill runs was small, as might be expected, being only 0.3 revolution in 1000 revolutions for inflation 55.

The slip with lower inflation became negative on the down-hill run, that is, the tire lagged behind, thus again proving that lower air pressure is accompanied by reduced slip.

These results have some interest, as showing the magnitude of rear-tire slip in one type of automobile. The same method of observation is about to be applied to a high-powered car, and also to one equipped with balloon tires. (E. H. Lockwood, Mem. A.S.M.E., Assistant Professor of Mechanical Engineering, Sheffield Scientific School, Yale University, in *Yale Alumni Weekly*, vol. 34, no. 7, Oct. 3, 1924, pp. 185–186, 1 fig., *e*)

POWER-PLANT ENGINEERING (See also Heating: New Process of Plant Heating)

Fuel Economy in Superpower Stations and Small Power Stations

WHILE the author admits that the larger and more up-to-date power plants show marked improvements in efficiency in recent years, he calls attention to the fact that by far the largest proportion of the fuel used for industrial purposes is consumed in the smaller plants, in many of which, as, for example, plants at collieries, the efficiency is very low.

The author further calls attention to the considerations which make immediate displacement of the smaller plants both difficult and financially unwise. He believes that the true line of progress in the conservation of our fuel resources is still to improve the plant and working efficiency of the *smaller* power plants and boiler installations. A small power station when scientifically controlled can be operated with high efficiency, and the special problem of the moment is how to provide the skilled supervision necessary for putting good methods into practice in the small plant.

This, in the writer's opinion, will be solved by applying the principle of "coöperation" to their supervision, and by making use of some organization with an expert staff of fuel chemists and engineers at its command, in order to raise the efficiency of these plants to a higher level. Voluntary organizations of this kind have been found to work well and to lead to remarkable improvement in the efficiency of small boiler plants abroad, and if backed up by Government support there is no doubt they will yield favorable results in this country. The Government might assist in this development by appointing chemical engineers under the new (British) Smoke Abatement Bill in each district, with powers similar to those of the alkali-works inspectors.

This applies, of course, primarily, to British conditions. (John B. C. Kershaw, F. I. C., in *The Power Engineer*, vol. 19, no. 224, November, 1924, pp. 411–413, 3 figs., *g*)

Steam Used by Surface-Condenser Auxiliaries

THE author points out that the obtaining and maintaining of higher vacuum in power plants is accompanied by greater power demand for driving auxiliaries. To illustrate the magnitude of the steam consumed by the steam-driven auxiliaries of two large surface condensers operating with steam from turbines, Fig. 9 is given. From this it will be observed that for surface condensers

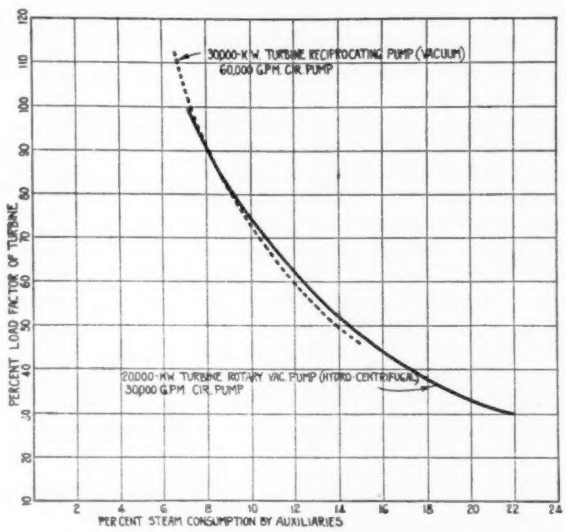


FIG. 9 STEAM CONSUMPTION OF SURFACE-CONDENSER AUXILIARIES

of from 20,000 to 30,000 kw. capacity, the steam consumed by the condenser auxiliaries range from 7 per cent at full load to 14 per cent at half-load with the percentage still greater at lower loads. The amount of condenser auxiliary power that one is justified in using depends on the ability of the main generating unit to pay for high vacuum by higher operating efficiency. In Fig. 10 one curve shows the theoretical saving that should result from increasing the vacuum from 27 to 29.5 in. on a turbine designed for a vacuum of 28.5 in. The other curve shows what a test revealed as to the actual savings that the increased vacuum did effect. In the original paper a chart is given that illustrates in a graphic manner just how much power one is justified in expending to obtain a higher vacuum, as well as a table that shows the power consumption of surface-condenser auxiliaries for several types of turbines. From these data it would appear that the subject of power consumption of the surface-condenser auxiliaries is of sufficient importance to warrant careful attention both of designing and operating engineers. (John D. Morgan in *Power Plant Engineering*, vol. 28, no. 22, Nov. 15, 1924, pp. 1135–1136, 3 figs., *p*)

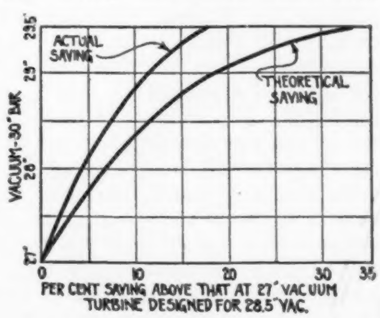


FIG. 10 SAVINGS EFFECTED BY INCREASED VACUUM

Foaming of Boiler Water

NOT only is foaming in boiler water little understood but the terms "foaming" and "priming" are somewhat indiscriminately ascribed to three distinct boiler phenomena, namely, actual foam on the surface of the water, nearly violent ebullition, and small bubbles throughout the mass of the water.

The author discusses the causes of foaming and priming and presents a physico-chemical theory of foaming based on Bancroft's (Applied Colloidal Chemistry, 1921, p. 268, McGraw-Hill Book

Co.) principles of the chemistry of foams, from which it would appear that the only essential for the formation of a foam is that there shall be a distinct surface film; in other words, that the concentration in the surface layer shall differ perceptibly from that in the mass of the liquid. In boiler water these films if caused by the usual inorganic salts, such as sodium salts, are not viscous enough to have more than a momentary existence and therefore do not cause serious trouble. But, if at the same time freely divided solid matter is present, such as loose scale and sludge, the films are stabilized and a persistent foam results.

This has been confirmed by a series of experiments in the course of which about 500 cc. of water was heated in glass flasks over a burner. In these experiments it was found that neither sodium salts alone nor finely divided insoluble matter alone produce foaming, but a white foam was produced whenever any of the sodium salts were present in sufficient concentration with any one of the insoluble materials. This would explain why such a confusion has existed as to the relation between foaming and salt content of boiler water.

For the prevention of foaming of the sort caused by mixtures of dissolved substances and finely divided solid matter, it is recommended that a trace of castor oil be introduced into boiler water. It would appear that extremely little castor oil is necessary to stop foaming almost instantly. (*Industrial and Engineering Chemistry*, vol. 16, no. 11, November, 1924, pp. 1121–1125, *etA*)

RAILROAD ENGINEERING

Testing Steam Locomotive by Regeneration on Electric Locomotive

THE American Locomotive Company recently built a three-cylinder locomotive for the South Manchurian Railway and was interested in securing accurate data for determining the mechanical efficiency at various speeds, cut-offs, and loads. An arrangement was made to carry out the tests on the test track of the General Electric Company at Erie, Pa., using one of the electric locomotives built for the Mexican Railways and equipped with regenerative braking. A check on the calculations was made by using one electric locomotive motoring and the other regenerating, and giving the effect of a pump-back test in which the substation supplied the losses. The value of the test lies in the fact that because of the accuracy of electrical instruments it was possible to determine the drawbar pull being exerted by the steam locomotive much more accurately than by the use of mechanical measurements. The data of the tests are given in the original article. Among other things it was found that this locomotive accelerated far more rapidly than the two-cylinder type. Indicator cards have also shown very good equalization of power. Primarily designed for freight service with wheels 54 in. in diameter and long maximum cut-off, this locomotive is said to have easily attained a speed of 63 m.p.h. with only about a two-mile run to accelerate. (*Railway Age*, vol. 77, no. 17, Oct. 25, 1924, pp. 733–734, 2 figs., and *Railway Review*, vol. 75, no. 17, Oct. 25, 1924, pp. 611–615, *d*)

Fireless Locomotives

AMONG the many difficulties experienced with fireless locomotives is the fact that although a pressure of 0.5 atmos. may be sufficient to operate these locomotives, they often fail to start with a steam pressure as high as 2 atmos., particularly when one valve has just been closed and the other side of the cylinder is getting the steam with the piston rod in a comparatively unfavorable position.

It is claimed that the source of trouble may be overcome by providing the locomotive with a starting steam tank of comparatively small dimensions, to be filled simultaneously with the main tank but independently thereof. If the pressure in the main tank has fallen so low that the locomotive is unable to start, an auxiliary valve is opened which admits the high-pressure steam into the valve chest. As only a few cylinder fillings of this steam have to be used to start the engine, a comparatively small tank is sufficient. The main and auxiliary valves are, of course, so interconnected that only one set can be opened at a time, and the auxiliary valves are further so arranged that they close automatically as soon as the driver releases the lever governing them.

In the particular installation shown in Fig. 11, the auxilary valve *c* admits high-pressure steam from the auxiliary tank *a* into the valve chest *d*. The auxiliary valve *c* is so interlocked with the main valve *e* that only one of them can be held open. The tank *a* having a capacity of 0.3 cu.m. (10.5 cu. ft.) is filled at the same time as the main tank *b* whose capacity is 12 cu.m. (423.76 cu. ft.) (Doctor of Engineering Metzeltin in *Hanomag Nachrichten*, Year 11, no. 131, September, 1924, pp. 150–151, 3 figs., *d*)

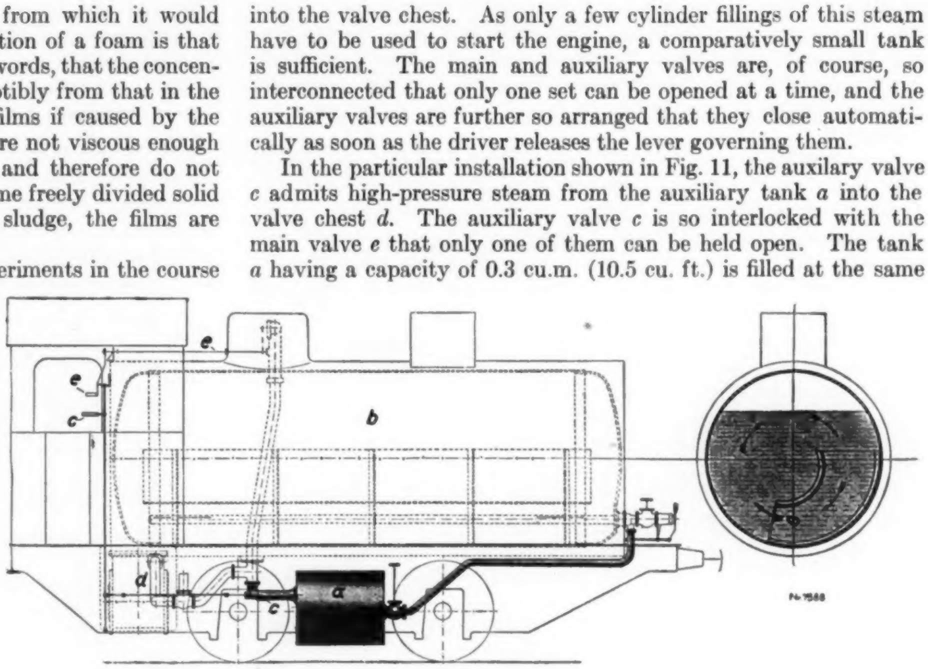


FIG. 11 STARTING DEVICE ON THE HANOMAG FIRELESS STEAM LOCOMOTIVE

Detroit, Toledo, and Ironton Electric Locomotives

THE December, 1924, issue of MECHANICAL ENGINEERING (p. 904) contained a description of a new type of electric locomotive recently installed on the so-called Ford Railroad (Detroit, Toledo, and Ironton), together with a statement of the advantages claimed for it. The following quotation as to its disadvantages may therefore be of interest.

"The outstanding disadvantage of this type of locomotive is that it must 'carry its substation about on its back' and that each one of these portable substations must be big enough to provide full-load current for the traction motors. When the substations are stationary and are located along the right of way, the substation capacity does not have to be as great as the connected locomotive load as more than one substation can supply power to a locomotive, and in cases where a number of locomotives work in one district, all of them seldom, if ever, require full-load current simultaneously. Balanced against these factors are the advantages offered by the fact that this type of locomotive can use a high-voltage alternating-current trolley, the direct-current motors used have characteristics which are best for traction purposes, and the control apparatus is extremely simple and effective." (Editorial in *Railway Electrical Engineer*, vol. 15, no. 11, November, 1924, p. 372, *g*)

SPECIAL PROCESSES

Closing Tube Ends by Spinning and Welding

IN THE CASE considered in the article here abstracted the ends of the tubes were required to be closed in a half-spherical form. The material was first-quality cold-drawn steel tubing about $2\frac{3}{4}$ in. in diameter with a wall thickness of approximately $\frac{1}{4}$ in.

An old medium-duty engine lathe having a hollow spindle, and a specially designed chuck for holding the tubing and at the same time insulating the spindle from the heat produced in the tube while being spun, were employed for the job. The tubes were cut to a length slightly greater than that called for by the finished dimensions, and the outer edge of the end to be closed was turned to a radius, as shown at *A* in Fig. 12. To speed up the spinning the end of the tube was heated to a dark red before being put in the machine chuck, where it was rotated at high speed.

The forming or spinning tool was a blunt-ended piece of high-speed steel, mounted on the cross-slide by means of a special at-

tachment which permitted it to be swung in accordance with the radius to which the closed end of the tube was to be formed. First the spinning tool was brought into contact with the walls of the tube and swung around. This operation was repeated, the tool being moved forward step by step after each swinging or sweeping operation, until the end of the tube was closed to a half-spherical shape. The heat produced by the friction of the tool against the metal increased the temperature, and as the metal was forced closer and closer toward the center, where it thickened as the diameter diminished, the heat became so intense that it melted the metal. At that point the tool was swept across the end so that a perfect weld was obtained.

With the method described, the tube passed through three

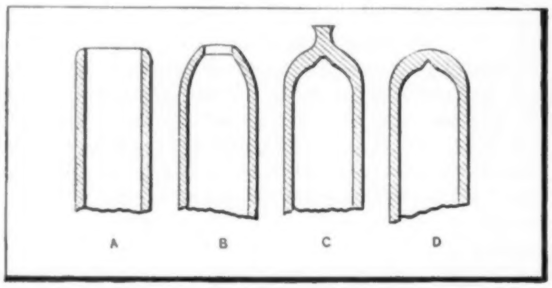


FIG. 12 CLOSING TUBE ENDS BY SPINNING, HEATING, AND WELDING

stages, as indicated at *B*, *C*, and *D*. The view at *B* shows the end of the tube as it appeared at the beginning of the spinning operation. The view at *C* shows the end of the tube with the metal forced in toward the center, so that it forms a bottom-like projection which is so hot that a final sweep of the tool will weld over the end of the tube and remove the bottom-shaped portion, leaving the end spherical in shape, as indicated at *D*. About 30 hp. was required to drive the lathe when performing this operation, and the spindle speed was approximately 4000 r.p.m. The time required was only 3 min. per tube. (*Machinery* (London), vol. 25, no. 631, Oct. 30, 1924, p. 134, 1 fig., *d*)

Blast-Furnace-Slag Pipe

DESCRIPTION of an application of the Dresler process for the manufacture of pipe from blast-furnace slag without the use of any binder. In the Dresler process as applied to the manufacture of brick, the material is first pressed in a machine and then hardened in a special chamber by means of gases containing large amounts of carbon dioxide. Since neither lime nor cement has to be used as a binder and no coal is used as fuel, the brick thus produced proved to be cheaper than the regular clay brick.

The process involves the use of two molds made of sheet iron or steel, one in place of the usual core and the other as the mold proper. The space between the two is then filled layerwise by ground slag and slag sand, each layer being tamped down by hand. The molding is done on a light car, and as soon as the mold has been filled the inner and outer sheet-metal shapes are very carefully removed; the car is then rolled with great care into the chamber where it is subjected to the usual hardening process by gases containing carbon dioxide. The gases used for this purpose are taken by a suction fan from the hot-blast stoves. It takes two days to complete the hardening of the pipe, and when properly made it is not inferior in strength to cement pipe. (Doctor of Engineering Friedr. Riedel. Communication from the Bureau of Blast-Furnace-Slag utilization of the Society of German Iron Makers, abstracted through *Stahl und Eisen*, vol. 44, no. 39, Sept. 25, 1924, pp. 1173–1174, 1 fig., *d*)

STEAM ENGINEERING (See Railroad Engineering: Fireless Locomotives)

TESTING AND MEASUREMENTS (See also Motor-Car Engineering: Tire Slip Tests; Railroad Engineering)

Measuring the Resistance of Monel Metal to Shock

THE author based his work on an article by Dr. Paul Fillunger entitled On Notched Bar Impact Tests (*Testing*, vol. 1, p. 23, 1924), in which are defined impact properties which are characteristic properties of the material.

Dr. Fillunger considered the energy required to produce fracture in a notched-bar impact specimen as consisting of two parts, the energy to produce deformation and the energy required to fracture the specimen. The energy to produce deformation is expressed by the formula

$$A_1 = \delta bhy$$

where b = width, h = height of the cross-section to be fractured, y = eccentricity, i.e., the distance of the center of gravity of the area of fracture from the axis of the bore of the notch, and δ = a characteristic property of the material representing its resistance to deformation. The energy to produce fracture is expressed by the formula

$$A_2 = 2\omega bh$$

where b and h are the dimensions of the fracture and 2ω is a characteristic property of the material representing its resistance to fracture. Then the total energy consumed in a notched-bar impact test is

$$A = A_1 + A_2 = \delta bhy + 2\omega bh$$

The "notch toughness" e is found by dividing the total energy by the area of the cross-section, or

$$e = \delta y + 2\omega$$

It is seen that the notch toughness e is not a characteristic property of the material but is dependent upon the eccentricity y. δ and 2ω are characteristic properties of the material and may be obtained by determining the notch toughness for several eccentricities.

The author determined the impact properties of monel metal as defined by Dr. Fillunger with a Charpy impact machine, using a

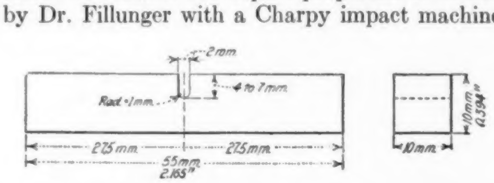


FIG. 13 TYPE OF SPECIMEN TESTED FOR NOTCH TOUGHNESS

bar shown in Fig. 13. To obtain various values of eccentricity y, the notch was cut to four different depths, 4, 5, 6 and 7 mm. (0.157, 0.197, 0.236 and 0.276 in.). Five specimens of each notch were tested. The following table gives the results of the tests:

Depth of notch, cm.	Eccentricity, y cm.	Energy of impact (average) m-kg.	Energy of impact (average) ft-lb.	Notch toughness, e m-kg. per sq. cm.	Notch toughness, e ft-lb. per sq. in.
0.4	0.40	15.61 ± 0.14	113	26.0	1210
0.5	0.35	11.57 ± 0.30	84	23.1	1080
0.6	0.30	7.85 ± 0.06	57	19.6	910
0.7	0.25	5.16 ± 0.03	37	17.2	800

It will be noted that the energy absorbed as expressed in meter-kilograms in the table has been given to more significant figures than the accuracy of notched-bar impact tests would usually justify. The average deviation from the mean has also been given in order that the reader may have some idea of the agreement between individual tests. The reason why these values of the energy absorbed have been given is that if we consider the values of the notch toughness as significant to only two figures when expressed in meter-kilograms per square centimeter, we find by substituting such values of e and y in the equation $e = \delta y + 2\omega$ there is obtained 60 m-kg. per sq. cm. (1 m-kg. per sq. cm. = 46.67 ft-lb. per sq. in.) for δ and 2 m-kg. per sq. cm. for 2ω for all combinations of e and y. Ordinarily one would suppose that such an agreement indicated quite accurate determinations of these two properties, but this is not true. If we solve for δ and 2ω using values of e and y given in the table above, we get values of δ ranging from 48 to 70 m-kg. per sq. cm. and for 2ω, —1.4 to +5.2 m-kg. per sq. cm. A better valuation of these results may be obtained by combining only those results which were obtained on notches which varied at least 2 mm. in depth. Then we get values of δ ranging from 58.7 to 64 m-kg. per sq. cm. and for 2ω 0.5 to 2.5 m-kg. per sq. cm., with average values of δ = 61 m-kg. per sq. cm. and 2ω = 1.8 m-kg. per sq. cm.

From this and data obtained by Dr. Fillunger it would appear

that monel metal compares favorably with such materials as steel and wrought iron.

Those properties of a material which represent its resistance to rupture in impact are usually expressed by stating the energy required to rupture a specimen in impact. For any material this energy varies with different types of specimens, therefore a method whereby the resistance of a material to rupture in impact may be determined and expressed independently of the type of specimen would be an addition to our methods of testing. It remains to be seen whether this method proposed by Dr. Fillunger can be applied so as to give characteristic properties which may be considered in selecting materials for a specific purpose. (R. G. Waltenberg, Research Laboratory, International Nickel Co., Bayonne, N. J., in *Chemical and Metallurgical Engineering*, vol. 31, no. 17, Oct. 27, 1924, pp. 657–658, *e*)

Testing Structural Steels Under Alternating Stresses

THE oldest way of testing materials in the form of rods or bars under alternating stresses is shown in Fig. 14, where the ends, *b* and *c* of the test piece *a* are located in ball bearings and driven at *e*. The bar carries in the middle the bearing *d*, which in its turn carries a load *G*. The bar is therefore stressed in bending and its every fiber is alternately pulled or compressed, the maximum stress being at the periphery of the bar in the middle, i.e., at *d*, and the bar is subjected to an alternating stress which varies from a certain maximum to a certain minimum.

The disadvantage of this arrangement lies in the fact that the maximum bending moment is applied to the bar at or under the locus of application of the load, i.e., *d*. Because of the fact that the load is applied just where the maximum moment is, there occur additional stresses of an indeterminate magnitude, the result of which is that rupture always starts at the place where the bearing *d* is located. Furthermore, since the magnitude of these additional stresses is unknown it is impossible to determine the true magnitude of the stress which brings about rupture.

To obviate these difficulties Wöhler proposed the arrangement shown in Fig. 15, the main feature of which is that instead of a single bearing *d* there are employed two bearings d_1 and d_2, located equidistant from the end bearings of the bar. Because of this the bar in the part between d_1 and d_2 is stressed under a constant moment $M = Gs$, and by reducing somewhat an area of the bar in the middle it is possible to shift the rupture from the places where the load is applied (d_1 and d_2) to somewhere in the middle of the bar, say, at *F*.

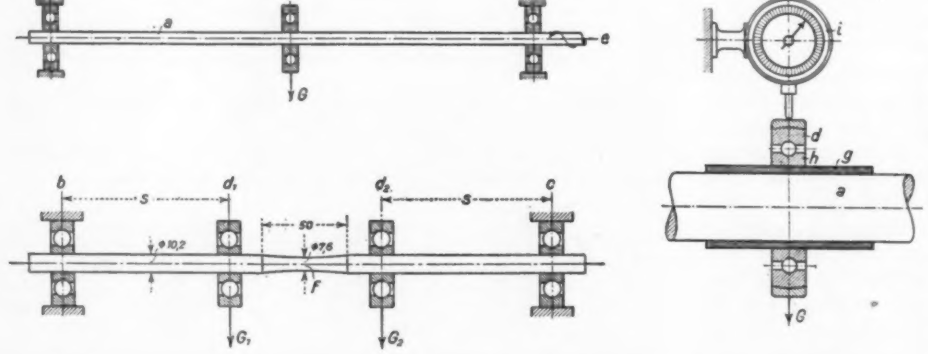
The author in his work at Braunschweig used another arrangement shown in Fig. 16 where a single bearing was employed but between the bar and bearing a layer of cardboard *g* about 1 mm. (0.04 in.) thick (Fig. 16) was inserted, the purpose of this being to equalize the stresses transmitted from the bearing with its load to the bar.

The result of the use of the cardboard insert was that about half of the pieces tested broke outside of the location of the ball-bearing race *h*, the fracture occurring at places where the strength of the bar appeared to be impaired by some reason or other. This would prove the contention of the author that the use of the cardboard insert did not have an undesirable effect on the transmission of stresses to the test bar.

Not only this but in a number of cases the cracks which finally brought about the rupture did not even start from the surface of the bar but from minute defects located in the interior of the metal.

There is another difficulty in connection with these tests which has to be clearly understood. The arrangement shown in Fig. 1 is merely diagrammatic and its actual execution is by no means as simple as would appear at the first glance. The load *G* on the bar cannot be applied by a simple suspension of weights as the forces with which one has to deal are entirely too great for it, and furthermore as oscillations would be initiated in the bar and would increase the stresses in an indeterminate manner. It becomes necessary, therefore, to produce the loading on the bar by the medium of lever transmission working on knife-edge supports. Practice has shown, however, that these lever transmissions when working over a considerable period of time easily get out of order, which may affect the results of the tests. Furthermore, it is important to see that no bending moments are transmitted to the end bearings *b* and *c* (Fig. 14) as these also may affect materially the stresses on the bar.

In order to discover the presence of factors of this character which might pervert the test results quite materially, the Ruthart gage *i* was set on to the bearing *d* in order to determine the uppermost position of *d* before and after the application of the load. From the difference between the two positions the bending of the bar *f* (as measured) is determined and this is compared with *f* (as computed), the computation involving the dimensions of the bar, the magnitude of the weight *G*, and the modulus of elasticity of the material. If the difference between the two values of *f* (i.e., as measured and as computed) exceeds 4 per cent in either direction, an investigation is made and this, incidentally, is not always as easy as would appear at first glance. As a matter of fact, there have been cases where the difference between the two values was of the order of 25 to 35 per cent and it took a search of many days to discover the causes of such a wide divergence.



FIGS. 14 TO 16 TESTING ARRANGEMENTS FOR DETERMINING STRENGTH OF MATERIALS UNDER ALTERNATING BENDING STRESSES

(Upper left hand—original Wöhler layout; lower left hand—modified Wöhler layout; right hand—Föppl arrangement with cardboard strip *g* between test bar and load-carrying bearing.)

Just to show how reliable and instructive tests with this apparatus may be, the author cites a case where two bars of presumably the same kind of structural steel were tested. The first bar broke in the middle under a load of 50 kg. per sq. mm. (71,000 lb. per sq. in.) while the second bar broke under a load of 8 kg. per sq. mm. (54,000 lb. per sq. in.), the rupture occurring about 9 cm. (3.5 in.) from the middle. The actual load at the point of rupture was therefore 28 kg. per sq. mm. The fracture was then more carefully investigated and it was discovered that the workman after polishing the bar had carelessly touched it with the polishing wheel at the point where subsequently the fracture occurred. This produced on the surface a cut barely visible to the naked eye 2 sq. mm. (0.003 sq. in.) in extent and $^1/_{40}$ mm. (0.001 in.) deep, but such an apparently insignificant injury to the bar produced a reduction of strength under alternating loads of the order of nearly 50 per cent. It is therefore very important to understand that the alternating bending-stress tests are materially affected by the microscopically small surface defects, such as unavoidably occur in the polishing of the test piece.

The remainder of the article, which cannot be abstracted because of lack of space, is devoted to the subject of the determination of the transformation of energy into heat in the tests and to the question of damping. (Prof. Otto Föppl in *Schweizerische Bauzeitung*, vol. 84, no. 18, Nov. 1, 1924, pp. 215–218, 6 figs., *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Hardness and Hardness Testing[1]

The Kind of Clarification Needed in Ideas Regarding Hardness—The Two Purposes of Hardness Testing—Uniformity Tested by Hardness—Hardness Tests in Specifications

By L. B. TUCKERMAN,[2] WASHINGTON, D. C.

"HARDNESS" in common parlance represents a hazily conceived conglomeration or aggregate of properties of a material, more or less related to each other. These properties include such varied things as resistance to abrasion, resistance to scratching, resistance to cutting, ability to cut other materials, resistance to plastic deformation, high modulus of elasticity, high yield point, high strength, absence of elastic damping, brittleness, lack of ductility and malleability, high melting temperature, magnetic retentivity, etc. This confusion under the one designation "hardness" results from the fact that there is a rough parallelism in these properties in a large number of materials. The fact that "hardness," thus conceived, is a conglomeration of different, more or less unrelated properties makes it impossible to correlate any one definite, measurable property with all the current implications of hardness.

So far from possible is such a complete correlation that we are not even able to give a reliable conversion table to connect 500 kg. Brinell hardness with 3000 kg. Brinell hardness, and much less can we convert scleroscope or scratch hardness (Mohs scale) into Brinell hardness.

This does not mean that under the hazy conglomeration of properties which are included in the common understanding of hardness, there are not included very important properties of the material.

Nobody doubts that the "hardness" of the diamond is one of its most important physical properties, nor that it is necessary to accurately control the "hardness" of metal-cutting tools or of balance knife edges, nor that the difference between "hard" and "soft" glass is of great technical importance, nor that there is a great difference between "hard" and "soft" woods or between "hard" candy and chocolate creams, a difference which is of considerable commercial importance.

It does, however, mean that the properties implied by the term "hardness" in these different cases are so heterogeneous that they cannot represent definite, accurately comparable properties of the materials in the sense that, for example, density, moduli of elasticity, specific heat, etc. represent definite and accurately comparable properties of the materials.

The Kind of Clarification Needed in Ideas Regarding Hardness

The clarification needed in our ideas about hardness is therefore not an all-inclusive definition of hardness, but a careful separation of the heterogeneous group of properties now included under "hardness" into as small a number as possible of definite, measurable physical properties which shall define all the technically valuable physical properties now included under that name. This will require a revision of nomenclature. There are two ways in which this can be done:

1 The limitation of the use of the word "hardness" to the particular one of these properties which is deemed most important or which is thought to embody most nearly the underlying hazy conception of hardness. In that case a new set of names must be adopted to cover the remaining properties now grouped under "hardness." A suggestion even more radical than this has recently been made[3] to drop entirely the use of the word "hardness" until a definite physical meaning for the term has been agreed upon. In the meantime it is suggested that we speak of Brinell numbers, Herbert numbers, Rockwell numbers, etc. Much can be said in favor of this suggestion. If adopted, it would do much to remove the idea that these numbers should in some way be directly convertible one into the other.

2 The adoption of a series of qualifying adjectives to distinguish between the different properties. This, although abstractly less desirable, is perhaps the more practicable, since we already have such terms as "scratch hardness," "scleroscope hardness," "cone hardness," "Brinell hardness," etc.

Illustrations of both of these ways of clarifying ideas and clarifying nomenclature are numerous in the history of physics. For instance, the word "force" originally included such varied concepts as energy, power, impulse, field strength (gravitational, electrical, and magnetic), voltage, electric current, chemical affinity, rate of chemical combination, velocity, and other more or less unrelated ideas having in common only the general underlying idea of the intensity of a physical phenomenon somehow capable of producing motion. As ideas concerning these phenomena became clarified the word "force" came to be more and more limited in its application to purely mechanical phenomena. The other ideas included under the name acquired new names, "energy," "power," etc. or received qualifying adjectives which distinguished them, as "electromotive force," "magnetomotive force," etc.

Value of Recognizing this Need

Our knowledge of the phenomena included under the general term "hardness" has not progressed enough to make it possible as yet to outline such an improvement in the nomenclature of the subject, but much misunderstanding and confusion can be prevented by recognizing that a clarifying improvement in nomenclature is necessary. A recognition of that fact would prevent futile arguments as to whether a scratch test or a penetration test gives a "true value of hardness." It would also tend to lessen the number of persons who desire to have a table which will convert "scleroscope hardness" or "Rockwell hardness" into "Brinell hardness." The time gained could better be spent in determining whether a scratch test, a penetration test, an abrasion test, or other hardness tests can be so standardized as to give consistent and useful results in any particular commercial or engineering problem, such as the acceptance of materials under specification, or to investigating more fully the underlying phenomena of hardness, with a view to obtaining a more thorough understanding of the subject.

The Two Purposes of "Hardness" Testing

In attempting an analysis of the technically valuable physical properties of materials which are included under the general term "hardness," it will be necessary to keep clearly in mind two essentially different purposes for which hardness tests are made. In the first, the test, although a "hardness" test, is not primarily to determine "hardness." It is not necessary nor important, although in some cases it may be desirable that the test determine whether the material is "hard" enough for the use to which it is to be put. Its purpose is solely to ascertain by a convenient non-destructive test whether the material is in the physical state which has, by other (in general destructive) tests, been shown to be suitable. Any other sufficiently sensitive, convenient, and reliable non-destructive physical test would serve the purpose as well.

In the second, the "hardness" of the material, or more specifically some of the special properties which are ordinarily loosely grouped together under the term "hardness," are an essential factor in the usefulness of the material. Here also it is possible to use a hardness test merely as a check on the uniformity of preparation of the material, but such a limitation of its use deprives it of a large part of its potential value as a criterion of the suitability of the material. Unfortunately our knowledge of hardness is so fragmentary that in most cases we are temporarily forced to accept this limitation even where "hardness" is essential to the purpose for which the material is intended.

The immediate field of hardness tests in practical application lies in their limited use as a convenient, non-destructive test for uni-

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Engineer Physicist, U. S. Bureau of Standards.

[3] Editorial in Mechanical Engineering, vol. 46, no. 8, August, 1924, p. 502.

formity. This use, though limited, is already of great practical importance and will become more important with the introduction of more rapid and more reliable methods of testing.

Uniformity Tested by "Hardness"

Since the test is to be a test of the quality of the material, all effects due to size and shape of the specimen must be eliminated. This does not mean that the results of the tests must be independent of the size and shape of the specimen, but only that, in case the results do depend upon its size and shape, the test shall only be used to compare the quality of specimens in which the important dimensions are the same. In some cases this may only require that certain dimensions (e.g., thickness in sheet metal) be the same, but in others it may require that all the specimens compared be identical in size and shape. This latter is particularly true of impact hardness tests on small specimens where shape and size have a large influence on the results.

With effects due to size and shape eliminated, differences in the test results beyond the experimental errors involved surely indicate lack of uniformity in the quality of the specimens tested. It does not, however, follow that uniformity in the test results indicates uniformity of the material. First, the test may be unsuited, through lack of sensitiveness, to show significant differences in the material, either because of insensitiveness of the particular instrument used or because wide variations in some important quality of the material cause only slight variations in the particular "hardness" tested. Second, and more important, materials may differ in many ways, so that the identical results of one "hardness" test on two different materials by no means insures the identity of all their properties. Their identical "hardness" may be due to compensating differences in other important qualities, some tending to increase the particular "hardness" tested, and others tending to lower it.

In order that uniformity in the results of any one particular test may safely be relied upon to indicate uniformity in the quality of the material, it is necessary that the material tested be uniform in chemical composition and that it be subjected to supposedly uniform mechanical and heat treatment, or in other words, that the specimens to be compared result from the same process of manufacture.

Under these circumstances, if the test used has been shown to be sufficiently sensitive to indicate significant differences of all the important qualities of the material, usually uniformity of the results of hardness tests may safely be relied upon to indicate uniformity in the material tested, and also, as a consequence, to indicate that the manufacturing processes are satisfactorily controlled.

This is the purpose served by nearly all the hardness tests in current use, and it is the investigation of this field of hardness testing which promises to yield technically valuable results most easily and most quickly. For this purpose all questions as to what the particular hardness test measures, whether it measures "true hardness" or something entirely different, are beside the point, as are also all questions as to general relationships between the different types of hardness tests, except in so far as they may incidentally throw light on the particular suitability of a particular test in detecting lack of uniformity in a particular material. The very nature of the test—as a convenient, non-destructive criterion of uniformity—contemplates its application to all or a large proportion of the material and not, as in the case of tensile or other destructive tests, to a relatively small number of samples. The prime requisite is, then, a convenient test which is as sensitive as possible to small changes in the physical state of the material and consistent enough so that significant differences in the material are not masked by the unavoidable errors of observation. There can be no one best test, but in each case the test must be chosen to fit the particular material and particular size and shape of object involved. This does not mean that we should indefinitely increase the already too numerous variants of the different "hardness" tests. It seems probable that a relatively few well-standardized tests should cover all practical variations in material and size and shape of specimen. A secondary and yet important consideration in finished pieces is the amount of permanent deformation left by the test. This must not be so great as to impair the usefulness of the tested piece. This consideration is, however, secondary. The lack of an obvious permanent deformation of the tested piece which would interfere with its usefulness can only be urged as an advantage of a particular test when the test has been shown to be a sufficiently sensitive and reliable criterion of the desired uniformity.

As an example of the confusion which may be avoided by keeping clearly in mind the purpose of these tests, the hardness testing of thin sheet material may be cited. Much effort has been expended in attempts to free such hardness tests from the influence of the necessary backing plate; a consideration of the purpose of the test makes it clear that the influence of the backing plate is immaterial, provided that it is not so large as to mask significant differences in the material to be tested, and provided it may be kept constant enough to give constant results in the same or duplicate specimens. The relation of the hardness reading on thin specimens to the reading on thick specimens of like material is also of no importance, so long as the tests are confined to judging the uniformity of specimens of the same thickness.

For a large range of materials the effect of the backing block is readily maintained constant by using a "glass hard" quenched steel block. The time and effort spent in attempting to make the readings independent of the nature of the backing block would in many cases be more profitably spent in increasing the sensitiveness of the method to changes in the physical properties of the sheet, and obviating errors due to irregular contact between the sheet and its backing.

"Hardness" Tests in Specifications

The question of the value of hardness tests in material specifications has been much discussed, but our lack of knowledge of the subject has hindered the introduction of such tests into specifications. Our knowledge probably is still too incomplete to justify the introduction of hardness tests, as such, into specifications, but a clear realization that "hardness" tests as tests of uniformity occupy a field distinct from "hardness" tests as tests of "hardness" would have opened the way for the introduction of hardness tests into many specifications where uniformity of material is a prime essential. For this purpose it is not necessary to know what hardness is nor what a proper hardness of the material would be. It is only necessary to determine what variation in "hardness" (measured in any convenient and consistent way) represents an undesirable lack of uniformity of the material. It often happens that material, thoroughly suited to a given purpose, may be manufactured by widely different processes out of materials of widely different chemical compositions. Under these conditions the "hardness" of suitable material of the two kinds will, in general, also be different, although the properties essential to the particular purpose may be practically identical.

In such a case it is obviously impractical to include among specifications of tensile strength, yield point, elongation, etc. are quirement that the "hardness" should lie within specified limits, since proper "hardness" limits which would insure satisfactory results for one material or one process of manufacture might be altogether unsatisfactory with another material or another process of manufacture.

On the other hand, it should be possible to specify ranges of "hardness" values suitable for rather broad material classifications, within which a purchaser might expect satisfactory uniformity of a given lot of material of the same chemical composition and manufactured by the same process. For example, a specification might read: "In any lot of 100 pieces, any piece whose Brinell hardness number, for 3000 kilograms, differs by more than 5 per cent from the mean of the lot shall be rejected." The proper range of values to be specified would, of course, differ for different classes of material, but there is a far greater present possibility of establishing satisfactory ranges of fairly wide application than there is of specifying satisfactory limits of "hardness" which shall not be altogether too narrow and special for general application. In many large manufacturing plants today material is inspected by hardness tests and accepted or rejected on criteria practically equivalent to a specification of this kind. From these plants it should be possible to collect information leading to the establishment of proper ranges of hardness for different classes of materials.

Another method of embodying hardness tests as tests of uniformity in a specification where uniformity is a prime requisite is to use the hardness test for the selection of samples for the destructive (tensile, impact, cold bend, etc.) tests. At present these specimens

are selected at random and usually the cost involved prohibits more than a very few such tests, leaving a very large uncertainty as to whether the specimens which happened to be selected were really representative of the lot from which they were taken. A provision that a non-destructive hardness test should be made of all the pieces of the lot and that those showing the lowest and highest hardness numbers should be submitted to the destructive tests, would reasonably insure, as no specifications at present insure, that the properties of every piece in the lot lay within the limits shown by the samples tested to destruction. The value of such a clause in a specification for material where the failure of a single piece may result in large property loss or even loss of life, can not be overestimated.

These suggestions are intended only as illustrations. Other and better methods of introducing hardness tests into specifications will probably be suggested. The only essential is the recognition that it is not necessary to await a satisfactory clarification of our conceptions of hardness to make use of these valuable tests in specifications. So long as the purpose of the tests is confined to the limited, yet important, field of testing for uniformity, there is sufficient technical information at hand which, if properly assembled, would make them already available as a valuable addition to many material specifications.

Testing Hardness for "Hardness"

The immediate usefulness of "hardness" tests in testing uniformity should not be allowed to obscure the real need for a fundamental investigation of "hardness." After all, the testing of "hardness" as such is a field in which research work is much needed. To make hardness tests serve their full purpose it is not sufficient to use them merely for the comparison of similar materials similarly treated.

By a proper study it should be possible to make them the basis for a comparison (preliminary, at least) of different materials differently treated. For this purpose it will be necessary to analyze carefully in each case the use for which the material is designed and determine, so far as possible, which of the varied "hardness" properties of the material are of greatest importance in that use. The hardness test or tests which are chosen must then be such as to measure so far as possible these particular properties.

Although much has been published on the subject of hardness, attempts at analysis of this kind have been all too few. We need to know far better than we do now just what is the difference between the "hardnesses" which are needed in a high-speed cutting tool, an automobile spring, a permanent magnet, a ball for a ball bearing, etc. and what are the tests which will best determine them. The problem is complicated and it is too much to hope that rapip progress will be made in its solution; nevertheless with a clear understanding that it is not one but many properties of the material which are under investigation, ultimate success may confidently be expected.

Inspection Methods

By EARLE BUCKINGHAM,[1] HARTFORD, CONN.

IN GENERAL, inspection should be employed as a preventive and not a cure. Inspection methods which will prevent faulty parts from being produced are of far more value than those which merely sort good parts from bad. Too often, however, inspection is considered as a sorting process only. Despite every precaution, however, faulty parts appear. Some sorting is therefore necessary, but this is a minor and not a major duty of inspection.

Considering first the product itself, all essential functioning and mating surfaces should be inspected. If the drawings are properly made and dimensioned, these surfaces are readily identified. However, to dimension such drawings properly and to establish tolerances which can be met readily in production and yet insure a product which will function properly, requires more thought and experience than any other task of production.

Many of us have had the experience of helping to put a new model on the market. So many times there have been false starts, changes in equipment, changes in design, salvaging of parts, etc. for the first year or two of production. As a very conservative estimate, not less than fifty per cent of such work and expense can be avoided by giving the drawings and specifications the study they require at the start.

A careful observance of the general principles stated in the S.A.E. Handbook will do much to save the expense of so many needless changes after production is started. To quote a few extracts from this handbook:

> Tolerances are necessary in commercial specifications only because of inability to produce absolutely identical parts.
>
> Only one dimension in the same straight line can be controlled within fixed limits, that is, the distance between the cutting surface of the tool and the locating or registering surface of the part being machined. Therefore it is incorrect to locate any point or surface with tolerances from more than one point in the same straight line.
>
> Every part of a mechanism must be located in each plane. Every operating part must be located with proper operating allowances. After such requirements of location are met, all other surfaces should have liberal clearances.
>
> Dimensions should be given between those points or surfaces that it is essential to hold in a specific relation to each other. This applies particularly to those surfaces in each plane which control the location of other component parts. Many dimensions are relatively unimportant in this respect. It is good practice in such cases to establish a common locating point in each plane and give, so far as possible, all such dimensions from these common location points. In every case the locating points on the drawing, the locating or registering points used for machining the surfaces, and the locating points for measuring and gaging should all be identical.
>
> The initial dimensions placed on component drawings should be the exact dimensions that would be used if it were possible to work without tolerances. Tolerances should be given in that direction in which variations will cause the least harm or danger. When a variation in either direction is equally dangerous, the tolerances should be of equal amount in both directions.
>
> The initial clearance, or allowance, between operating parts should be as small as the operation of the mechanism will permit. The maximum clearance should be as great as the proper functioning of the mechanism will permit.

Component drawings dimensioned in accordance with the foregoing rules not only give the inspectors directly the information they require, but also show the tool designer the holding point he must use in the design of the manufacturing equipment. Improperly dimensioned component drawings lead only to confusion.

When the positions of the dimensions are governed more by the convenience of the draftsman than by the essential interrelation of the surfaces dimensioned, either the dimensions must be ignored or unnecessary expense in production will be entailed. If all measurements were absolute it would make little difference, perhaps, how the various positions were determined. But as they are not absolute, this matter of what measurements are made becomes of vital importance. If two measurements are made where one only was required, double the variation or amount of tolerance is required. Or if the amount of variation is definitely limited, it will require holding two dimensions to one-half the tolerance otherwise available.

The foregoing is an attempt to indicate what should be inspected on the product. The reason why such points should be measured is because they control the essential interrelations and operating clearances of the various parts of the mechanism.

The product itself, however, is not all that should be inspected. The tools and equipment used to produce this product should receive even greater attention. Proper inspection here will save the production of faulty parts. The ideal conditions would be to have tools and equipment of such reliability that periodic tests of the equipment alone would insure correct results. This condition is almost attained by such processes as die casting, sub-presses,

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Extracts from an address at a meeting of the Cleveland Section of the A.S.M.E., Nov. 3, 1924.

and some automatic screw machines. The more nearly any process approaches this condition, the smaller the percentage of the actual product which requires inspection. Time spent in the inspection of tools and equipment is well invested. The inspection of these can, and should, be more complete and elaborate than the inspection of the product.

The inspection of the product falls logically into two divisions: first, the process inspection, and second, the final inspection.

Process-inspection operations should occur immediately after every machining operation that finishes an important functional surface. The tolerances established should be as liberal as conditions will permit and should be rigidly enforced here. Nothing will do more to promote a high quality of product than the establishment of proper tolerances and their strict enforcement. Operations which are not producing to the specified requirements should be stopped at once, and the set-up or tools should be corrected before proceeding again. The practice of piling up faulty parts until the production schedule forces them to be passed "on disposal" cannot be condemned too severely. If the established tolerances are right, such a practice is gambling with the good name of the plant. If they are unnecessarily severe, they should be corrected. The main object of process inspection is to keep a close check on the set-up and operation of the manufacturing equipment and to cull out faulty parts as soon as possible after the defect occurs so as to save the expenditure of further effort on the production of unsatisfactory parts.

The final inspection should be handled in a more judicial manner. The object here should be to accept all parts that will function properly and to reject those that will not. If the process inspection has been properly carried out, this inspection would consist of functional inspections only, with perhaps a visual inspection for general quality of workmanship. In the final inspection minor and unimportant deviations from the specifications can be ignored, while they should be enforced in the process inspection, because nothing should be left undone while the material is being shaped to size and form to make the product meet the specifications; while after the work has been completed, nothing should be scrapped that will be entirely serviceable and satisfactory in the completed mechanism.

The best point of vantage to judge the effectiveness of the inspection methods selected is on the assembly floor. If the parts as produced assemble and function properly it is complete evidence that all essentials are under proper control. If they do not, it is equally conclusive evidence that some further control is necessary. This does not necessarily mean that the correct solution is to provide additional inspection. Oftentimes a minor improvement in the manufacturing equipment which improves its reliability is the proper action.

For example, in one automobile plant considerable difficulty was experienced in the timing of the engine. An investigation showed that the trouble was due to the varying positions of the cams. Further investigation showed that the operator of the cam-grinding machine, would, after grinding two or three cams, find that due to warpage in hardening perhaps one side of the cam had much more stock to remove than the other. In order to speed up his operation he would shift the dog on the work to equalize the amount of material to be removed, not realizing that a difference in the size of the cam was of less importance than the angular position of the cams. Two or three such shifts of the dog before the camshaft was completed introduced very troublesome errors in the product.

Either of two solutions would solve this problem. First, testing facilities to check each camshaft could be provided so that any shifting of the dog by the operator could be detected. Second, the dog and its means of location could be altered so that the operator could not shift their position. Of the two solutions, the second would probably be the more economical and satisfactory one.

Inspection equipment should be kept as simple and inexpensive as possible. One step to this end is the adoption and use of as many standards as possible for various parts, surfaces, and tolerances. Such a procedure results in many of the benefits and economies of quantity production where they would not otherwise be available. The more that different plants and industries agree on common standards, the more far-reaching these benefits become.

Any definite inspection system should be developed around its particular product and manufacturing plant. The best inspection methods are so closely interwoven with the particular manufacturing methods employed that the use of any fixed system developed without regard to all factors involved would be not only ineffective but also unduly expensive. The best system of any sort is always the least that proves effective.

A.S.M.E. Boiler Code Committee Work

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given interpretations of the Committee in Cases Nos. 461–471 inclusive, as formulated at the meeting of October 28, 1924, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

Case No. 461

(In the hands of the Committee)

Case No. 462

Inquiry: Is it permissible, under the requirements of Par. P-218, to use instead of through stays under the tubes of an h.r.t. boiler, diagonal braces? The type of diagonal brace referred to is one that reduces the area of metal in contact with the sheet to a minimum.

Reply: It is the opinion of the Committee that when stays are required below the tubes, through stays must, under the requirements of Par. P-218, be used, and that the use of any stays attached to the boiler shell is not permissible.

Case No. 463

Inquiry: Is it permissible, under Par. P-250 of the Boiler Code to use the prosser method of expanding tubes in fire-tube boilers provided they are subsequently rolled and beaded as that paragraph specifically requires?

Reply: Attention is called to the fact that the expanding of tubes by the prosser method is permitted in place of rolling only for tubes not exceeding $1^1/_2$ in. in diameter. It is the opinion of the Committee that there is nothing in the Code to prohibit the prossering of tubes larger than $1^1/_2$ in. in diameter, provided they are subsequently rolled and beaded, or rolled, beaded, and welded around the edge of the bead, as required by Par. P-250.

Case No. 464

Inquiry: Will a method of supporting h.r.t. boilers, 84 in. in diameter and larger, which consists of suspending the shells from properly designed cross-beams resting on pilasters built into the side walls of the setting so as to be entirely free from the firebrick linings thereof, meet the requirements of the Boiler Code?

Reply: Attention is called to the fact that Par. P-323 of the Code requires all h.r.t. boilers over 78 in. in diameter to be supported from steel hangers by the outside-suspension type of setting, independent of the side walls. It is the opinion of the Committee that this requirement cannot be met unless the overhead supporting beams rest on piers of either steel, brick, or other substantial construction which are entirely independent of and not bonded into the side walls of the boiler setting.

CASE NO. 465

Inquiry: Inasmuch as it has been stipulated in Case No. 453 that the lowest visible point of a water gage shall not, for low-pressure heating boilers, be located lower than the point specified for fusible plugs, an interpretation is requested of Par. H-64 in the Low-Pressure Heating Boiler Section of the Code, which refers to the "lowest safe water line."

Reply: It is the opinion of the Committee that the lowest safe water line of a heating boiler is that at which the heating surfaces of the boiler are either covered with water or are not exposed to products of combustion until these products have passed over not less than 75 per cent of the total heating surface of the boiler.

CASE NO. 466

Inquiry: An interpretation is requested of the application of that portion of Par. P-253 of the Code which prohibits the punching of "such holes" in material more than $^5/_8$ in. thick. The first sentence refers to "all holes in braces, lugs or sheets for rivets or staybolts," and inquiry is made as to whether the term "sheets" would cover heads, and as to whether holes for other purposes than above named may be punched in material more than $^5/_8$ in. thick.

Reply: It is the opinion of the Committee that the prohibition of punching holes in material more than $^5/_8$ in. thick applies to all rivets or staybolt holes in sheets, whether for use as heads or shell plates. It is pointed out, however, that this prohibition does not apply to holes intended for other purposes than for rivets or staybolts.

CASE NO. 467

Inquiry: Is it the intent of Par. P-308 to permit the connection or attachment of a blow-off pipe for a boiler to a return connection which is of the same size or larger than that specified for the blow-off pipe, when such blow-off outlet is not and cannot be attached to the shell before the boiler leaves the shop?

Reply: Par. P-308 permits the use of a large opening for a water return connection to the boiler and to this return pipe a blow-off not exceeding $2^1/_2$ in. pipe size may be connected. It is pointed out by the Committee that it is not ordinarily possible to attach the blow-off outlet before the boiler leaves the shop where the boiler is built, but that this connection is properly made upon installation in the field must be verified by the proper authority.

CASE NO. 468

Inquiry: Is it permissible, under the requirements for the construction of steel-plate boilers in the Low-Pressure Heating Boiler Section of the Code, to attach steam outlet and safety-valve flanges to the shell by autogenous or fusion welding?

Reply: It is the opinion of the Committee that in providing for the welding of steel heating boilers, it was anticipated that the welded joints should be considered for the purpose as equivalent to riveted joints under the restrictions outlined therein and therefore that there is no objection to the welding of such outlet flanges for low-pressure heating boilers.

CASE NO. 469

Inquiry: An interpretation is requested as to the application of the term "the equivalent" as it appears in the last line of Par. P-321. Is it to be understood that brass or other non-ferrous pipe will not be considered the equivalent of steel pipe or tubing or wrought-iron pipe for use at pressures above 200 lb. per sq. in.?

Reply: It is the intent of the last sentence of Par. P-321 to prohibit the use of brass, copper or other non-ferrous pipe or tubing whose strength is materially reduced or impaired when subjected to the temperatures corresponding to steam pressures above 200 lb. per sq. in. Attention is called to a typographical error in the last sentence of this paragraph, the beginning of which should read: "For steam pressures over 200 lb. per sq. in., etc."

CASE NO. 470

Inquiry: Is it necessary, when using the outside-suspension type of setting as specified in Par. P-323 of the Code for h.r.t. boilers less than 78 in. in diameter, to adhere to the requirement therein for the girthwise spacing of rivets in the hangers, or may this requirement be waived in view of the smaller diameters of boilers?

Reply: It is the opinion of the Committee that where the boiler does not exceed 78 in. in diameter, the requirement in Par. P-323 for the girthwise spacing of rivets in the hangers does not apply.

CASE NO. 471

Inquiry: Inquiry is made as to whether there is not an error in the second filling material analysis for electric welding in Table H-8 of the Heating Boiler Section of the Code? The phosphorus limit appears to be much too high.

Reply: In the second section of Table H-8 of the Heating Boiler Section of the Code, referring to material for filling rods for electric welding, an obvious clerical error has been made in that the second and third lines should be transposed so as to make the manganese content read "not over 0.40 to 0.60 per cent," and the phosphorus "not over 0.06 per cent."

Modification in Report on Code for Unfired Pressure Vessels

THE Report of the Sub-Committee of the Boiler Code Committee on Code for Unfired Pressure Vessels was presented in the December, 1924, issue of MECHANICAL ENGINEERING as a Final Report, to be printed and issued as "Rules for the Construction of Unfired Pressure Vessels" unless criticisms are received which, in the opinion of the Boiler Code Committee and the Council of the A.S.M.E., will warrant changes. At the meeting of the Boiler Code Committee held on December 1, in connection with the Annual Meeting of the Society, the Report was carefully proofread, and in addition suggestions received for the correction of typographical errors were acted upon and a few changes of minor importance made, resulting in the following list of modifications. It is the hope of the Boiler Code Committee that the Report on this Code will, together with these modifications, prove satisfactory so that the Code can be printed and issued at an early date.

Paragraph Number	PROPOSED MODIFICATIONS
Matter in italics preceding Par. U-1:	In first line, omit the words "boilers and other."
U-1	Second line, insert after "diameter" the words "having a volume of." Omit the words "in volume."
	Fourth line, omit the words "or iron."
U-2	Fourth line, omit the word "readily."
U-3	Insert center heading: "Safety Valves for other than Noxious Liquids or Noxious Vapors."
	Second line, omit last word "of."
	Third line, replace first word "about" by "between;" replace "or about" with "and."
U-6	Fourth line, replace "water" by "liquid."
U-11	Omit side heading "Corrosive Chemicals" and replace by center heading "Corrosive Substances."
U-15	Second line, insert after "allowable," the word "working."
U-20	Fifteenth line, replace "in." by the word "inches."
U-62	First line, insert after "diameter," the words "subject to interior corrosion."
U-64	Fifth and sixth lines, omit the words "vessels with fusion welded joints shall be tested to three times the working pressure, and."
U-65	Fifth line, replace third word "and" with the word "or."
U-66	Second line, omit the words "the class."
	Change wording following "(Mfrs. Name)" in stamping, to read, "The stamping shall not be covered permanently with insulating or other material."
U-73	Second line, insert after "and," the words "if necessary."
U-78	Add the following sentence at the end of the paragraph: "Vessels fabricated in accordance with Par. U-23*a*, after the test herein specified, shall have the pressure raised to three times the maximum allowable working pressure, and held there three minutes."
U-88	Second line, insert after "attached," the words "to forge-welded vessels."

Engineering and Industrial Standardization

Canadian Electrical Code

THE American Engineering Standards Committee reports that under the auspices of the Canadian Engineering Standards Association a Canadian electrical code is being formulated to cover both fire and casualty hazards. A large representative sectional committee has been organized on which the Dominion and Provincial Governments, and various industrial bodies are represented.

The code will be based largely on the American National Electrical Code and the National Electrical Safety Code. Its first draft is now in course of preparation, arrangements having been made by which H. F. Strickland of the Hydro-Electric Power Commission and W. F. McKnight of the Nova Scotia Technical College have been giving full time to this work.

International Comparisons of Candlepower Standards

AT THE time of the adoption of the "international candle" the carbon-filament lamp was the only type of lamp, and the standards by means of which the unit was established and maintained were of this type.

As tungsten-filament lamps came into wider use it became necessary to establish standards of this type, and comparisons were made in 1913 and 1914 with the National Physical Laboratory of Great Britain. The outbreak of the war interfered with the completion of this work, since it made international comparisons impracticable. Consequently the Bureau established its own standards of the tungsten vacuum type and later of the gas-filled tungsten type with the expectation that slight adjustments in value might be necessary when international comparisons could be made.

During the past summer some lamps of both types have been taken to several European laboratories for preliminary measurements. The results indicate not merely that satisfactory agreement has been maintained in the case of the carbon standards, but also that the tungsten vacuum standards independently established are in unexpectedly close agreement in France, England, and the United States. Arrangements have been made for more precise comparisons and detailed results of the measurements will be published later.

Radio Standardization

COINCIDENT with the rapid development of interest in the manufacture and use of radio apparatus has been a steady increase in the organized movement to bring about standardization of the component parts of the various instruments. On July 8, 1924, a Sectional Committee on the Standardization of Apparatus and Nomenclature was organized under the procedure of the American Engineering Standards Committee. It has 26 members, representing various producing, consuming, distributing, and general radio interests. Its technical work will be carried on by sub-committees on the following subjects: Transmitting and receiving sets and installations, component parts and wiring, electron tubes, electroacoustic devices, power supply, and outside plant. The following officers were elected at the organization meeting: John H. Marecroft, Chairman, L. E. Whittemore, Vice-Chairman, and A. M. Goldsmith, Secretary.

A.S.T.M. Standards Revised to 1924

TRIANNUALLY the American Society for Testing Materials issues as a bound volume the standard specifications which are in effect at the time of publication. The volume for 1924 contains 220 specifications, methods of test, definitions of terms, and recommended practices. They are grouped as follows: A, Ferrous Metals; B, Non-Ferrous Metals; C, Cement, Lime, Gypsum, and Clay Products; D, Miscellaneous Materials; and E, Miscellaneous Subjects.

Before a specification receives the formal approval of the Society as a Standard, it is published for one or more years as a Tentative Standard. A considerable number of these A.S.T.M. Standards have been presented to the A.E.S.C. for approval as American standards.

Copies of the 1924 volume of Standards may be secured from C. L. Warwick, Secretary, The American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa., at the price of $11.00 in cloth binding and $12.50 in half-leather binding.

New A.S.T.M. Volume of Tentative Standards Now Available

THE 1924 volume of Tentative Standards issued by the American Society for Testing Materials has just come from the press. It represents a complete revision of the 1923 volume and its 763 pages contain the 185 Tentative Standards issued by the Society. They are grouped as follows, the number in each group being indicated:

Steel and Wrought Iron (11)	Timber (5)
Non-ferrous Metals (18)	Waterproofing (16)
Cement, Lime, Gypsum and Clay Products (28)	Insulating Materials (7)
Preservative Coatings (10)	Shipping Containers (4)
Petroleum Products and Lubricants (17)	Rubber Products (3)
Road Materials (45)	Textile Materials (10)
Coal and Coke (3)	Thermometers (3)
	Miscellaneous (5)

The term "Tentative Standard" as distinguished from "Standard" is applied to a proposed standard which is printed for one or more years for the purpose of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward the adoption of such tentative standards by formal action of the Society. Copies of this volume may be secured by addressing the Secretary of the A.S.T.M., 1315 Spruce Street, Philadelphia, Pa.; price $7 in paper binding and $8 in cloth binding.

Logging and Sawmill Safety Code

THE Logging and Sawmill Safety Code is now published as an approved Tentative American Standard, having been formulated by a sectional committee under the regular procedure of the American Engineering Standards Committee, the Bureau of Standards acting as the sponsor organization. It may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 60 cents per copy.

The Code covers the hazards incident to the felling of timber, the conveying of sawed logs from the stream to the railroads or rivers, transportation by logging railroads including safety specifications for such roads, river driving, snow and ice roading, rafting and fluming. There is also a section on the use, storage, and transportation of explosives and inflammable liquids, as a large proportion of the accidents in the lumber industry are due to these causes.

Part 2 of the Code covers sawmill operations, including mill design and layout, equipment for handling saw logs, protection of sawing machinery, together with edgers, gang saws, resaws, trimmers and slashers. Additional sections cover conveyors used for handling material and also miscellaneous machinery, such as lath and shingle equipment. Part 3 covers yard operations, including dry kilns, lumber stackers, and railroad tracks located between mill yards, as well as machinery for handling lumber.

It is designed as a guide for state codes and for voluntary adoption by lumber manufacturers. That the Logging Code is needed is indicated by statistics prepared by the Prudential Insurance Company, which give 837 as the total number of fatalities in this industry for the year 1916. Owing to the greater amount of lumber cut at the present time, this number is probably more nearly 1000 per year.

Correspondence

***Contributions** to the Correspondence Department of "Mechanical Engineering" are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on articles or policies of the Society in Research and Standardization.*

Formulas for Computing Economies of Labor-Saving Equipment[1]

To the Editor:

The formulas proposed for computing the economies of labor-saving equipment cover but one application of the generally accepted method of comparing costs on the basis of total annual costs. Total annual costs may be divided into fixed charges, which include all charges against the capital invested that continue whether the service is being rendered or not; and operating charges, which vary with the hours of service or with the output when the system is in operation. Capital invested is the primary element on which fixed charges are based, while hours of use is the corresponding factor in determining operating costs. This separation into two distinct groups readily lends itself to mathematical expression—either arithmetically or graphically—and in either form is perfectly general in its application. In fact, the mathematics is no more involved than the comparison of two or more expressions in the form of $a + bx$, and however complex the relation may appear when stated in words, it may be reduced to this simple form.

The fundamental formula may be stated:

Total annual cost = Fixed charges + Operating charges

The cost of a service conceivably may consist of fixed charges only, or the cost of a service may consist only of operating charges, as is sometimes assumed where labor is the principal element of cost. However, in the greater number of services of interest to the engineer, both elements are present.

The simpler problems of comparative costs will generally take one of the following forms: (1) The fixed charges and the operating charges of one service may be respectively greater than the fixed charges and the operating cost of a second service. The economical selection is here obvious and needs no mathematical expression. (2) The fixed charges of one service may be greater than the fixed charges of a second service, but the operating charges of the first service less than the operating charges of the second service. Since operating charges are assumed to increase directly with the hours of service, at some point, if the hours of use is expressed as a percentage of the total number of working hours in a year, the costs of the two services are equal. But if the total annual cost of the second service is less than the total annual cost of the first service, the point of equal cost will not be within the year, and this condition may become of interest when a plant is working beyond its normal capacity, as with overtime or two labor shifts. In this general case the hours of service per year becomes the guiding factor in the selection. If a system is used much, higher first cost with correspondingly higher fixed charges is justified, but if the system is little used, then lower first cost with increased operating cost gives the better economy. (3) The first service may have no fixed charges, but its operating charges are greater than the total annual cost of the second service. This is simply a variant of the second form (2), the fixed charges of one system becoming zero.

The formulas offered by the Committee are applicable to problems covered by the third form (3) and to these only, and entirely fail to meet the more general conditions of the second form (2). A comparison may be made between a process requiring hand labor only and a process using a machine, but no comparison is possible between two or more machines offered for the same purpose.

[1] A report on these Formulas was presented by the A.S.M.E. Materials Handling Division at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, and published in Mechanical Engineering for September, 1923.

The relation of interest to depreciation, the meaning of repairs, upkeep, and maintenance, the distribution of overhead—are all questions of real interest in any formal statement of cost analysis, but in the present instance it seems better to retain the terms as used by the Committee without comment.

A running summary of the general formula would be about as follows:

Let I = investment in dollars for the machine and its installation
I_{max} = maximum investment for equal cost of service
F = fixed charges in dollars = pI
p = fixed charges as a percentage of the initial cost = $100\,F/I$ = $(a + b + c + d)$ where
- a = percentage allowance on investment
- b = percentage allowance for insurance, etc.
- c = percentage allowance for upkeep
- d = percentage allowance for depreciation, etc.

O = operating charges in dollars; this would include wages or direct labor, together with overhead, fuel, or power, and supplies or other material consumed proportionally to the hours of service
X = a factor which may be the percentage of year during which the machine is used, or may be the percentage of plant capacity employed. In the comparison of machines or methods X is rather a significant figure, and has been variously defined as the breaking point, the change point, the capacity factor, the point of equal costs, or the point of no profits.

As two plants or machines are to be compared, subscript numerals will be used to designate items referring to the first plant and to the second plant.

Case 1. F_1 is greater than F_2 and O_1 is greater than O_2. Then
$F_1 + O_1$ is greater than $F_2 + O_2$ and
$F_1 + XO_1$ is greater than $F_2 + XO_2$
and it is evident that the second machine would be the more economical one to use.

Case 2. F_1 is greater than F_2, but O_1 is less than O_2. With X given,

$$F_1 = F_2 + X(O_2 - O_1) \quad \text{[I]}$$

$$I_{1\,max} = \frac{F_2 + X(O_2 - O_1)}{p_1} = F_1/p_1 \quad \text{[II]}$$

To find X, the other terms being given, use the equation

$$X = (F_1 - F_2)/(O_2 - O_1) \quad \text{[III]}$$

Case 3. $F_1 = 0$, that is, the first machine has no fixed charges but its operating charges O_1 are greater than O_2 of the second machine.

$$F_2 = X(O_1 - O_2) \quad \text{[IV]}$$

$$I_{2\,max} = \frac{X(O_1 - O_2)}{p_2} = F_2/p_2 \quad \text{[V]}$$

$$X = F_2/(O_1 - O_2) \quad \text{[VI]}$$

Formula [V] will be seen to correspond with Formula [I] given by the Committee; but [V] is only a form of [II], which together with [III] and [VI], will give that wider application sought by the Committee, but which is not given by their original formulas.

J. A. Brown.

New York, N. Y.

To the Editor:

The letter criticizing the Formulas for Computing the Economies of Labor-Saving Equipment, submitted by J. A. Brown, carries the implied charge that the Formulas Committee has claimed a scope for the formulas which is broader than its work warrants.

COMPARATIVE ECONOMIC ANALYSIS NO. 1

Showing values for Z and V, as per formulas recommended by A.S.M.E. Committee. Also yearly profit from operation in per cent on capital required.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination as to its comparative efficiency.

If No. 2 equipment is installed, and will be displaced by the use of No. 1 if found more profitable, the results given should be modified by the formula for that purpose, in which the unamortized capital value of No. 2, less its resale or scrap value, is equal to K.

No. 1 (designated by subscript numeral 1): 1 Apron Conveyor. Cost \$8640; operating 2160 hours per year; requires no operator; hp. of motor, 6; cost of electric current, 3 cents per kw-hr.

Operated for Equal Production in Comparisons with

No. 2 (designated by subscript numeral 2): 1 Electric Storage-Battery Truck. Cost \$2200; operating 1920 hours per year; requires 1 operator at 50 cents per hour; hp. of motor, 4; cost of electric power, 3 cents per kw-hr. This equipment is now installed.

Averaged Values. None.

No. 1 Apron Conveyor		1 year = 2400 hours		No. 2 Electric Truck	
One		Number of units employed		One	
$^1X_1 = 90\%$		Per cent of year employed	(X)	$^1X_2 = 80\%$	
$A_1 = 6\%$		Per cent on investment	(A)	$A_2 = 6\%$	
$B_1 = 3\%$		Per cent for insurance, etc.	(B)	$B_2 = 3\%$	
$C_1 = 7.5\%$		Per cent for upkeep	(C)	$C_2 = 20\%$	
$D_1 = 10\%$		Per cent for depreciation	(D)	$D_2 = 25\%$	
Total = 26.5%				Total = 54%	
E_1X_1 =	\$ 286	Cost of power, etc.	(E)	E_2X_2 =	\$ 190
...hr. at...	none	Cost of labor to operate	(S)	1920 hr. at 50 cents	\$ 965
...% of payroll	\$none	Cost of labor burden	(T_a)	30% of pay roll	\$ 288
$A_1 + B_1 + C_1 + D_1$ =	26.5%	Cost of fixed charges	(T_b)	$A_2 + B_2 + C_2 + D_2$ =	\$1188
	none	Value of increased production	(U)		none
	\$8640	Initial cost of equipment	(I)		\$2200
	none	Present value of equipment	(K)		\$1100
	\$2289	Yearly cost to maintain	(Y)		\$1188

FORMULA: $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$ FORMULA: $Y_2 = I_2(A_2 + B_2 + C_2 + D_2)$

Substituting, $Y_1 = \$8640 \times 26\frac{1}{2}\% = \$2289$ Substituting, $Y_2 = \$2200 \times 54\% = \$1188$

$E_1 - E_2 = \$286 - \$195 = \$91 = E$

$S_2 - S_1 = \$960 - \text{none} = \$960 = S$

$T_{a2} + T_{b2} - T_{a1} = \$288 + \$1188 - \text{none} = \$1476 = T$

$U_1 - U_2 = \$ \quad - \$ \quad = \text{none} = U$

$Y_1 = \$2289.60 = Y$

$A_1 + B_1 + C_1 + D_1 = 26.5\% = A + B + C + D$

FORMULA: Z = maximum investment justified $= \dfrac{(S + T + U - E)X}{A + B + C + D}$

Substituting, $Z = \dfrac{(\$960 + \$1476 + \text{none} - \$91)\ ^1100\%}{26.5\%} = \mathbf{\$8849}$

FORMULA: Z modified $= Z - K$

Substituting, Z modified $= \$8849 - \$1100 = \mathbf{\$7749}$

FORMULA: V = yearly profit from operation $= [(S + T + U - E)X] - Y$

Substituting, $V = [(\$960 + \$1476 + \text{none} - \$91)\ ^1100\%] - \$2289.60 = \mathbf{\$55.40}$

FORMULA: V modified $= V - (KA_2)$

Substituting, V modified $= \$55.40 - (\$1100 \times 6\%) = \mathbf{-\$10.60}$

Yearly profit in per cent $= \dfrac{V}{I} = \dfrac{\$\ldots}{\$\ldots} = \ldots\% + 6\% = \ldots.\%$

Yearly profit modified, in per cent $= \dfrac{V \text{ modified}}{I} = \dfrac{\$-10.60}{\$8640.00} = -0.1\% + 6\% = \mathbf{5.9\%}$

Yearly profit 5.9% + depreciation 10% = yearly amortization 15.9% = 6.3 years for complete amortization.

[1] "Per cent of year employed" is applied individually in Case No. 1, and Case No. 2 therefore becomes unity in the equation.

COMPARATIVE ECONOMIC ANALYSIS NO. 2

Showing values for Z and V as per formulas recommended by A.S.M.E. Committee. Also yearly profit from operation in per cent on capital required.

It is assumed that the use of equipment No. 2 is generally accepted practice, while No. 1 is under examination as to its comparative efficiency.

If No. 2 equipment is installed, and will be displaced by the use of No. 1 if found more profitable, the results given should be modified by the formula for that purpose, in which the unamortized capital value of No. 2, less its resale or scrap value, is equal to K.

No. 1 (designated by subscript numeral 1): 1 semi-automatic turret lathe. Cost \$6100; operating 2280 hours per year; employing 1 operator at 60 cents per hour; hp. of motor, 5; at 3 cents per kw-hr. Reduced occupancy of buildings valued at \$115.

Operated for Equal Production in Comparisons with

No. 2 (designated by subscript numeral 2): 2 Engine Lathes. Cost each \$2400 or a total \$4800; operating 2160 hours per year each, employing 2 operators at 70 cents per hour; hp. of motors, 3; total, 6 hp., at 3 cents per kw-hr. This equipment is now installed.

Averaged Values. None.

No. 1 One turret lathe		1 year = 2400 hours		No. 2 Two engine lathes	
One		Number of units employed		Two	
$^1X_1 = 95\%$		Per cent of year employed	(X)	$^1X_2 = 90\%$	
$A_1 = 6\%$		Per cent on investment	(A)	$A_2 = 6\%$	
$B_1 = 3\%$		Per cent for insurance, etc.	(B)	$B_2 = 3\%$	
$C_1 = 5\%$		Per cent for upkeep	(C)	$C_2 = 5\%$	
$D_1 = 10\%$		Per cent for depreciation	(D)	$D_2 = 7.5\%$	
Total = 24%				Total = 21.5%	
E_1X_1 =	\$ 250	Cost of power, etc.	(E)	E_2X_2 =	\$ 284
2280 hr. at 60 cents	\$1368	Cost of labor to operate	(S)	4320 hr. at 70 cents	\$3024
80% of pay roll	\$1094	Cost of labor burden	(T_a)	80% of pay roll	\$2419.20
$A_1 + B_1 + C_1 + D_1$ =	24%	Cost of fixed charges	(T_b)	$A_2 + B_2 + C_2 + D_2$ =	\$1032
	\$ 115	Value of increased production	(U)		none
	\$6100	Initial cost of equipment	(I)		\$4800
	none	Present value of equipment	(K)		\$1320
	\$1464	Yearly cost to maintain	(Y)		\$1032

FORMULA: $Y_1 = I_1(A_1 + B_1 + C_1 + D_1)$ FORMULA: $Y_2 = I_2(A_2 + B_2 + C_2 + D_2)$

Substituting, $Y_1 = \$6100 \times 24\% = \$1464$ Substituting, $Y_2 = \$4800 \times 21\frac{1}{2}\% = \$1032$

$E_1 - E_2 = \$250.00 - \$284.00 = -\$34.00 = E$

$S_2 - S_1 = \$3024.00 - \$1368.00 = \$1656.00 = S$

$T_{a2} + T_{b2} - T_{a1} = \$2419.20 + \$1032.00 - \$1094.00 = \$2356.80 = T$

$U_1 - U_2 = \$115.00 - \$0.00 = \$115.00 = U$

$Y_1 = \$1464.00 = Y$

$A_1 + B_1 + C_1 + D_1 = 24\% = A + B + C + D$

FORMULA: Z = maximum investment justified $= \dfrac{(S + T + U - E)X}{A + B + C + D}$

Substituting, $Z = \dfrac{\$1656.00 + \$2356.80 + \$115.00 + \$34.00)\ ^1100\%}{24\%} = \mathbf{\$17,340}$

FORMULA: Z modified $= Z - K$

Substituting, Z modified $= \$17,340 - \$1320 = \mathbf{\$15,980}$

FORMULA: V = yearly profit from operation $= [(S + T + U - E)X] - Y$

Substituting, $V = [(\$1656 + \$2356.80 + \$115 + \$34)\ ^1100\%] - \$1464 = \mathbf{\$2697.80}$

FORMULA: V modified $= V - (KA_2)$

Substituting, V modified $= \$2697.80 - \$1320.00 \times 6\%) = \mathbf{\$2618.60}$

Yearly profit in per cent $= \dfrac{V}{I} = \dfrac{\$\ldots}{\$\ldots} = \ldots\% + 6\% = \ldots\%$

Yearly profit modified, in per cent $= \dfrac{V \text{ modified}}{I} = \dfrac{\$2618.60}{\$6100.00} = 42.9\% + 6\% = 48.9\%$

Yearly profit 48.9% + depreciation 10% = yearly amortization 58.9% = 1.7 years for complete amortization.

[1] Per cent of year employed is applied individually in Case No. 1, and Case No. 2 therefore becomes unity in the equation.

SUMMARY OF ANALYSIS NO. 1

Recommendation

No. 2 equipment is recommended for the following reasons.

Comparative Efficiency

The efficiency of No. 1 over No. 2 equipment, covering a yearly return from operation of 6 per cent of its cost minus $10.60 representing a return of 5.9 per cent upon the capital invested, is not considered sufficient to constitute a governing factor in favor of No. 1 equipment.

Capital Requirement

The amount of capital required for No. 2 is less than for No. 1 by $6440.

Relative Flexibility

No. 2 equipment is more adaptable to employments other than that covered by the analysis, in the event of a change in organization or a change in the service to be performed. The truck can be used in any part of the factory and is efficient for long hauls. The conveyor is fixed as to location, and in this case the economical distance is exceeded.

Reserve Capacity

No. 2 equipment as shown by the analysis has 20 per cent of reserve capacity available for "Increased Production," which could be employed in general transportation about the factory.

The annual profit from such employment would be $150, which, if introduced into the analysis as an additional valuation for the factory U ("Increased Production"), would revise the results shown by the analysis relative to No. 1 equipment as follows:

Results Shown by Analysis Relative to No. 1 Equipment in Comparison with No. 2		Results Revised for Additional Value for U
Actual investment required	$8640.00	$8640.00
Maximum investment justified	$7749.00	$7180.82
Yearly profit from operation −6 per cent	−$10.60	−$160.60
Profit in per cent of capital invested, per cent	5.9	4.1
Time required for amortization of capital	6.3 yr.	7 yr.

SUMMARY OF ANALYSIS NO. 2

Recommendation

No. 1 equipment is recommended for the following reasons:

Comparative Efficiency

The efficiency of No. 1 over No. 2 equipment, covering a yearly return from operation of 6 per cent of its cost plus $2618.60 representing a return of 48.9 per cent upon the capital invested, is considered sufficient to constitute a governing factor in favor of No. 1 equipment.

Capital Requirement

The amount of capital required for No. 1 is greater than for No. 2 by $1300, which excess is considered justified by the higher efficiency obtained.

Relative Flexibility

No. 1 equipment is equally adaptable to employments other than that covered by the analysis, in the event of a change in organization or a change in the service to be performed. There is no material difference in the relative flexibility.

Reserve Capacity

No. 1 equipment as shown by the analysis has no material per cent of reserve capacity available for "Increased Production" which could be employed. No. 1 equipment occupies less floor space than No. 2, with consequent reduction in building cost and incidental heating, lighting, etc.

The annual profit for such employment would be $0.00, which if introduced into the analysis as an additional valuation for the factor U ("Increased Production"), would revise the results shown by the analysis relative to No. 1 equipment as follows:

Results Shown by Analysis Relative to No. 1 Equipment in Comparison with No. 2		Results Revised for Additional Value for U
Actual investment required	$ 6,100.00	....
Maximum investment justified	$15,980.00	....
Yearly profit from operation, 6%	$ 2,618.60	....
Profit in per cent of capital invested	48.9	....
Time required for amortization of capital	1.7 yr.	....

The writer, as a member of the Formulas Committee, wishes to point out that as the title clearly indicates, the Formulas for Computing the Economies of Labor-Saving Equipment are offered as applicable for comparing the relative efficiencies of mechanical and manual industrial processes. The following quotation from the Formulas Committee's report emphasizes this limitation: "Incidental items such as interest on investment, taxes, maintenance, depreciation, obsolescence, etc., in other words, 'fixed charges' or 'burden,' are currently accounted on the debit side when calculating the cost of substituting *mechanical processes* for *manual* ones. It seems, however, to have been unusual to make any contingent addition in calculating the monetary value of labor saved by improved methods."

Experience in the use of the formulas indicates, however, the Committee's representations as to their scope are not only not excessive, but might properly be greatly extended.

There are submitted herewith two analyses employing the formulas, the first of which meets Mr. Brown's criticism that comparison cannot be made between one process requiring the use of a machine and another process requiring the use of a machine. In this analysis the formulas give a definite answer for a case where an apron conveyor is used in one process and an electric storage-battery truck in the other process.

In analysis No. 2 is submitted an example as described in Mr. Brown's case (2). In this analysis Equipment No. 1 shows higher fixed charges but lower operating charges than Equipment No. 2. The formulas are perfectly adequate to handle this condition, and justify the selection of Equipment No. 1.

The examples given, which might be readily supplemented by others, while not designed to simulate practical conditions exactly in the valuation of the several factors, seem to indicate that the formulas are not subject to any important limitations in scope; they are however, recommended because of the accuracy in results obtainable through their use.

JAMES A. SHEPARD.

Montour Falls, N. Y.

TO THE EDITOR:

The writer submits herewith an equipment-estimate form which may be of interest as a practical application of the Formulas for Computing Economies of Labor-Saving Equipment. These forms are so arranged and tabulated that they can be readily used by equipment engineers.

For future reference it is well to number estimate forms, also to fill in the spaces allowed for the name of the product, the drawing numbers, and the type of new equipment under consideration.

Items and groups A, B, C, when filled in with the available data, will show a comparison between the present and proposed number of machine tools and men required to operate them, the capacity of the equipment, and the production requirements under normal business conditions.

Items and groups D and E show a comparison between the present and proposed machine and man time, also direct labor cost and the factory overhead charges or burden.

Items G and J show the earnings to be expected with the new equipment after the proper allowances have been made for items F and H covering the cost of power and supplies, etc., also the time the equipment must remain idle in case it has productive capacity in excess of the requirements.

Item and group K show the necessary allowance on the investment, for insurance, upkeep, and depreciation.

Item L shows the investment justified in order to have the new equipment pay for itself in the number of years or at the rate represented by the percentage of allowance for depreciation and obsolescence by item K_3.

Item M shows the actual cost of the new equipment.

Item R_1 shows the net operating profit if operating up to normal requirements only, having deducted the allowance under item and group K from the earnings, item J, as expressed by item P. It is interesting to note the rapid increase in the net profits if operating near the full capacity instead of at a low percentage of available productive capacity, the estimate form bringing out this fact very clearly.

Item R_2 shows the interest on the net profit which is applicable after the first year of operation or after any other period which might be selected.

Item S shows the return on the investment, from which can be estimated the number of years the new equipment will have to be operated before it has paid for itself through increased earnings, after which period items K and K_3 increase net earnings substantially.

This equipment-estimate form can also be used for comparing two alternative propositions, and if columns "present" and "proposed" are used as "Proposition No. 1" and "Proposition No. 2,"

EQUIPMENT ESTIMATE NO...102....SHEET..1....

PRODUCT....Textile Machine....PART....Stand....PATTERN NO.....LH 1.50..........................
DRAWING NO. 1A48..............................
OPERATION....Mill rail notch and top, bottom and toe..
PROPOSED EQUIPMENT....One 50″ × 5′ 4″ double-faced milling machine.............................

	Present	Proposed	Difference		
No. of machine tools	4	1	3		A
No. of men	2	1	1		B
No. of parts, capacity per hour	6	20	14		C
No. of parts, capacity per year (2500 hr.)	15000	50000	35000		C_1
No. of parts required per normal year	15000	15000	...		C_2
Machine time, minutes, each part	40	3	37		D
Men time, minutes, each part	20	3	17		D_1
Direct labor cost, each part	$ 0.24	$0.035	$0.205		E
Direct labor cost, 15000 parts	$ 3600	$ 525	$ 3075		E_1
Direct labor cost, 50000 parts	$12000	$ 1750	$10250		E_2
Burden at 200%, 50000 parts	$24000	$ 3500	$20500		E_3
	(assumed)		Total	$30750	E_4
Indirect savings through increased production or improved quality				$?	E_5
			Total	$30750	E_6
Cost of power, supplies, etc. (additional per year)				$none	F
Gross earnings				$30750	G
Part of normal year in operation				30%	H
Increased earnings over present method per year				$ 9225	J
Allowance on investment per year		6%			K
Allowance for insurance per year		2%			K_1
Allowance for upkeep per year		2%			K_2
Allowance for depreciation and obsolescence per year		10%			K_3
		Total		20%	K_4
Maximum investment justified				$46125	L
Initial cost of new equipment		$21736 (actual cost)		$21736	M
Value of equipment to be replaced (deduct) $?					N
Cost to keep new equipment ready for operation, per year		$ 4347.20			P
Net profit if operating it full capacity, per year		$26402.80		120%	R
Net profit operating it 30% of capacity, per year		$ 4877.80		22%	R_1
Interest on net profit, 30% of capacity, per year		$ 292.66		6%	R_2
Return on investment, 30% of capacity, per year				38%	S
Capacity increased				75%	T
Direct labor cost reduced				85%	U

Submitted by...............Date...............
Approved by...............Date...............

NOTE: E_1 = Production in normal year; E_2 = Production, full capacity; $E_3 = 2E_2$; $G = E_6 - F$; $J = G \times H$; $L = J \div K_4$; $P = M \times K_4$; $R = G - P$; $R_1 = J - P$; $S = M(K + E_3) + R_1 + (R_2)$

respectively, it will then show if the increased productive capacity of one equipment will justify its higher cost by the net profits on the difference between the cost of the two equipments, and it can thereby be determined whether or not this additional investment is justified.

F. O. HOAGLAND.

Biddeford, Me.

Weights Should be Indicated on Blueprints When Asking for Estimates on Castings

TO THE EDITOR:

Much time and expense could be saved by the jobbing foundries of this country if designing engineers would put approximate weights on all blueprints sent out for bids.

All weights must be figured when the design is made to get approximate costs, and if these values were put on the blueprints in all cases where a price per pound was desired, it would save a great deal of time in the engineering departments of the jobbing foundries and greatly expedite quotations.

We are frequently delayed days (and weeks, in many cases) in making prices because our engineering department is required to figure the weights from a large number of blueprints. Spread over a year, and applied to the industry as a whole, the loss of time in getting off quotations must run into a tremendous total.

Further, a high-class organization must be maintained to prepare quotations. Some of the castings are quite intricate and men of considerable experience are required to calculate their weights. This, of course, means expense, which finally is reflected in the cost of castings.

We might add that it is almost a universal custom to quote prices per pound on the estimated weights on all rough castings and on almost all work where no finish is required. This is true as regards ingots, billets, and forgings, which form a large part of our production, as well as our steel-casting business.

We respectfully submit that by giving attention to this matter much time and money can be saved and that ultimately the present great waste of both can be practically eliminated.

ERIE FORGE COMPANY,

Erie, Pa.

By T. E. Durban.

Proposed Standards for Herringbone Gears

TO THE EDITOR:

Mr. Tiemann's letter, as published in the December issue of MECHANICAL ENGINEERING, brings up a point in regard to the Proposed Standard for Herringbone Gears which deserves serious attention. As the report now stands, it is a combination of a dimensional standard with a metallurgical one, and the two elements are somewhat incongruous.

The standard would be greatly improved by subdividing it into the following separate and distinct specifications:

a Specification of tooth form and helix angle

b Specification for standard widths of grooves to suit the several generating processes

c Standard horsepower ratings based on yield point of material employed

d Recommended materials for herringbone gears with tables of physical properties.

By such a subdivision revisions could be made where necessary to meet new conditions with the minimum of disturbance. For example, if the proposed tooth form and helix angles are best for general purposes, this standard will remain unchanged. As new processes may be developed for generating the gears, which require wider or narrower grooves, the additional specification can be added to (*b*). If the adopted horsepower rating is a fair one, that will remain unchanged. If research or experience should develop a better one, a revised specification can be adopted. As various materials prove suitable for use for these gears they can be added to (*d*). If the specifications for the materials are revised by the originators of the specifications, those in the proposed standard can be revised accordingly. Leaving the specifications combined as at present brings up discussions and questions in regard to all of the several elements when but a single one is at issue.

EARLE BUCKINGHAM.

Hartford, Conn.

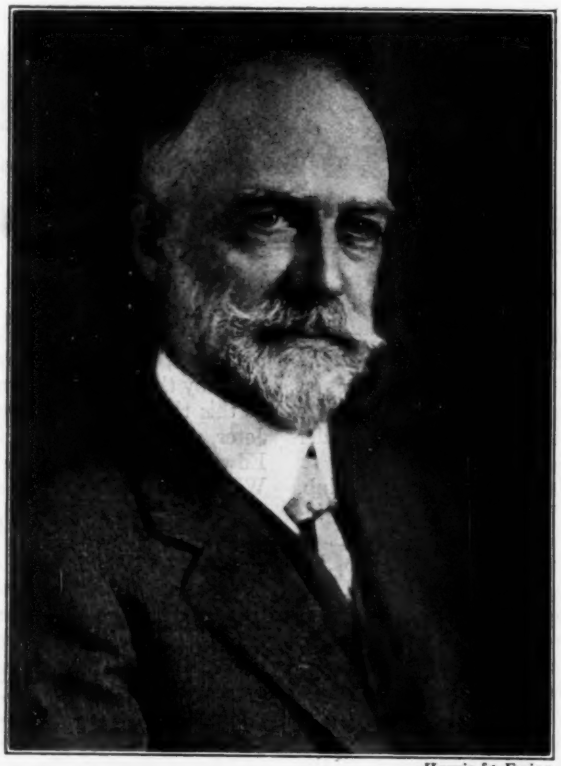
The Plauson Research Institute has applied for a patent for the utilization of the so-called "Colloid mills" whereby thoroughly homogenized mixtures of a pitch tar asphalt or bitumen with tar or mineral oils, are pressed through pipes at 350 to 450 deg. cent., where they are subjected for five to thirty minutes to a pressure of up to 200 atmospheres of pure hydrogen or some similar rich hydrogen containing gases. The combustible fluid, obtained in this manner, is said to be suitable for driving Diesel engines. If the result is as promised then, because of the short time required for the hydrogenation, the procedure would be a decided improvement over other existing methods. (*Power*, Nov. 25, 1924, p. 834.)

Forty-Fifth Annual Meeting of A.S.M.E.

New Standards Set in Breadth, Balance, Diversity of Program and Registration—Many Innovations Introduced—Technical Sessions of Unusual Interest Draw Out Valuable Discussion

THE FORTY-FIFTH Annual Meeting of The American Society of Mechanical Engineers established a mark of general excellence which will be hard to equal in forthcoming years. In the spirit of engineering fellowship displayed, in the breadth, balance, and diversity of its program, in the interest in the excursions and in the registration of 2174, which exceeded by three the largest previous record, that of 1920, this meeting set new standards.

The meeting opened on Monday, December 1 and the last session was held on Thursday, December 4, but the Council meeting and the feature excursion took place on Friday. The Third National Exposition of Power and Mechanical Engineering was held in the Grand Central Palace from December 1 through December 6, and was well attended by members of the Society.



Harris & Ewing

W. F. Durand
President, 1925
The American Society of Mechanical Engineers

Many radical changes were introduced into the program for this meeting and strenuous efforts were made to provide opportunities for acquaintanceship, which are so important in gatherings of this kind. In general, excellent results were obtained, and the many committees who contributed to the success of the meeting are to be heartily congratulated.

One of the innovations was that of having the Presidential address delivered on Tuesday evening instead of Monday, as formerly. A second departure from established custom was the institution of two general lectures, one on Tuesday afternoon and the second on Thursday afternoon. The first dealt with an economic subject and the second with science. Both were of intense interest to mechanical engineers. The revision of the social program provided a general get-together for members on Monday evening and a dinner on Wednesday evening, Thursday evening being left free for college reunions or as an opportunity for those who came to the meeting to enjoy the entertainment attractions that New York offers.

The celebration of the Carnot Centenary under the auspices of the Engineering Foundation and coöperating societies and institutions took place on Thursday evening, and many members of the Society availed themselves of the opportunity to hear the commemorative addresses of Dr. Michael Pupin and Dr. W. L. R. Emmet.

Special efforts were made by the Committee on Meetings and Program to have the papers available in advance of the meeting. Part of the papers appeared in a special Mid-November issue of Mechanical Engineering and the remainder were issued in pamphlet form on request. The publicity given to this method of issuing papers resulted in a severe tax upon the staff of the Society in filling the orders, but in general the scheme worked satisfactorily.

It is exceedingly difficult to select outstanding sessions of the meeting for special comment, but mention must be made of the valuable address of Assistant Secretary of War Davis at the National Defense Session, the papers of Dr. Marks and Dr. Lucke at the Oil and Gas Power Session, the two excellent sessions on Management, at one of which Dr. Taylor's paper on Shop Management, now twenty-one years of age was re-presented, the important Steam Power Session, and the four sessions of interest to machine-shop men. In this last respect the meeting was the strongest held in a long time, and the contributions, especially those on lubrication, were of great importance. The American Society of Refrigerating Engineers coöperated in an interesting session which brought out valuable discussion. The method of issuing papers in advance resulted in excellent discussion throughout the meeting, and in practically every session the arrangement of the program gave ample opportunity for adequate discussion.

Presidential Address

In his Presidential Address on Tuesday evening, Fred R. Low discussed American power resources and their control. The effect on civilization of greater utilization of power, and the problems confronting us in handling the available resources in the manner necessary to benefit posterity. He stressed the importance of conserving our present resources. Mr. Low's address appears as the leading article in this issue of Mechanical Engineering.

Following the address, the report of the Tellers of Election of officers was presented by the chairman, Dr. A. A. Adler. President-elect Durand was then escorted to the platform by Past-Presidents James Hartness and Dexter S. Kimball. Governor Hartness presented Dr. Durand, who formally accepted his new position. The Society then tendered a reception to the President and President-elect and the guests of the evening. This was followed by dancing.

Lectures

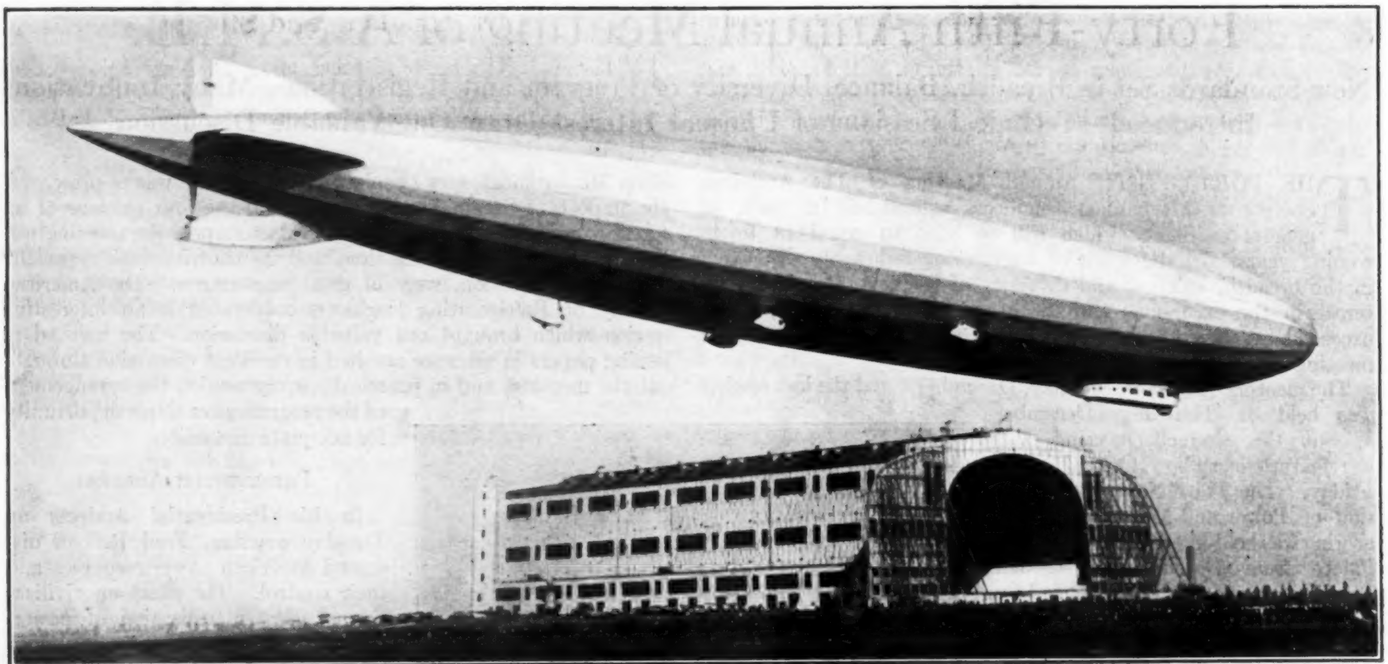
An important innovation in the technical program was the introduction of two lectures, one of economic and one of scientific importance. The economic lecture, a valuable discussion entitled Engineers and the American Petroleum Situation, by Dr. Julian D. Sears, Administrative Geologist of the United States Geological Survey, Washington, D. C., was delivered Tuesday afternoon. Dr. Sears' lecture appears in full in this issue of Mechanical Engineering.

The scientific lecture was given on Thursday afternoon and consisted of an exceedingly interesting presentation of the Properties of Matter under High Pressure, by Prof. P. W. Bridgman, professor of physics, Harvard University. Professor Bridgman dealt with the results observed when using hydrostatic pressures ranging from 150,000 to 600,000 lb. per sq. in. and the effects produced on materials under these pressures. His lecture will appear in the February issue of Mechanical Engineering.

Dinner and Social Program

The principal innovation in the Annual Meeting social program this year was the Dinner held on Wednesday evening, and there has possibly been no Society event in recent years so well received and favorably commented upon.

A mere telling of the events of the evening cannot possibly bring out the spirit which permeated the dining room of the Astor that night. That is an intangible something which, to be understood,



Underwood and Underwood

The "Los Angeles"

must be felt and participated in. But the spirit was there, and as a result membership in the A.S.M.E. means more to 581 of its members than it ever did before. One of the finest features of the evening was the presence of 77 men who had become members during the past year. Surely their introduction came under auspicious circumstances.

Conrad N. Lauer, President of the Philadelphia Engineers' Club, was toastmaster. He introduced President Low who in turn introduced three guests for the evening Charles F. Rand, Past-President and representative for the President of the A.I.M.E.; Farley Osgood, President of the A.I.E.E., and Ex-Governor Hartness, President of the A.E.C. He then introduced the past-presidents of the A.S.M.E. who were present, members of the Council, chairmen of standing committees and the secretary, Calvin W. Rice. Each rose for a moment in brief acknowledgment of his introduction.

At this point Mr. Rice took charge and introduced to the gathering each of the 77 new members of the Society present at the dinner. He then turned attention to three tables of "35ers," men whose Society membership covered a period of 35 or more years. There were thirty of them in attendance, largely through the efforts of Frederick A. Scheffler.

Dean Kimball and Dr. Livingston Farrand, President of Cornell University, were the speakers of the evening. Dean Kimball brought a message on the meaning of the scientific society to the engineer, while Dr. Farrand, a man of international reputation through his services as secretary of the National Association for the Study and Prevention of Tuberculosis and as director of tuberculosis work in France of the International Health Board, sounded a call to duty on the part of the scientifically minded professions, namely, medicine and engineering, as citizens of a great nation and of the world.

On Monday evening there was a Get-Together on the fifth floor of the building, at which dignity and technicalities were laid aside.

On Wednesday afternoon the customary Ladies' Tea was enjoyed by a crowd that taxed the capacity of the fifth floor of the building.

Council Meetings

The Council of the Society met twice during the Meeting, its first session being held on Monday morning, December 1. The principal business was the action by which each member of the Society will receive a copy of Volume 45 of Transactions bound in half morocco instead of in paper, as has been the custom for the past two years. On Friday morning, at the second meeting, the new officers of the Society were installed and the incoming President, William F. Durand, was presented with a gavel of ebony made by the students of Pratt Institute. The other officers installed at this time were Vice-Presidents Robert W. Angus, Sherwood F. Jeter, and Thomas L. Wilkinson, Managers John H. Lawrence, Edward A. Muller and Paul Wright, and Treasurer William H. Wiley. The Council reëlected Calvin W. Rice as Secretary.

Local Sections Delegates

Delegates from sixty of the sixty-four Local Sections of the Society met in an all-day session on December 1 to discuss common problems and get first-hand contact with many of the leaders in Society activities. Thomas L. Wilkinson, Chairman of the Local Sections Committee, presided at both the morning and afternoon sessions. Officers of the Society, chairman of its committees, and other leaders of its activities gave five-minute talks on important phases of Society work. At the joint luncheon of the Council and Local Sections Delegates brief remarks were made by President Low, President-elect William F. Durand, and Past-President Ambrose Swasey, the latter calling attention to the important work the Society is doing in publishing the Life of "Uncle John" Brashear. Fred Dorner, Chairman of the Milwaukee Section, extended a hearty invitation to attend the Spring Meeting of the Society in Milwaukee in May, 1925. A more complete account of the transactions of the Council and deliberations of the conference of Local Sections Delegates appeared in the December 7th and 22nd issues of the *A.S.M.E. News.*

Business Meeting—Presentation of Melville Bust

The important feature of the Business Session was the formal presentation of a bust of Admiral George Wallace Melville, Past-President and Honorary Member of the A.S.M.E. In the absence of Walter M. McFarland, President-elect Durand read the presentation speech which will appear in the February issue of Mechanical Engineering. The bust was purchased by personal friends of Admiral Melville in the Society and is the work of another friend, Samuel Murray, a sculptor of Philadelphia. The Committee for the purchase and presention of the bust consisted of Alexander C. Humphreys, Asa M. Mattice, Ira N. Hollis, Robert S. Griffin, William D. Hoxie, and Walter McFarland.

The Annual Report of the Council was summarized by Secretary Rice and then President Low announced the award of the Junior Prize to R. H. Heilman, of Pittsburgh, Pa., for his paper on Heat Losses through Insulating Materials. The first Student Prize was awarded to George Stuart Clark, of Stanford University, Cal.,

for his paper on Determination of the Gasoline Content of Absorption Oils, and was received for Mr. Clark by Dr. Durand. The second Student Prize was awarded jointly to L. J. Franklin and Charles H. Smith of Stanford University, Cal., and was received by Mr. Smith who came on from California for that purpose and also to present the paper at one of the technical sessions of the Meeting.

The Revised National (American) Standard Fire Hose Coupling Screw Thread and the Proposed Standard for Tolerances and Allowances for Machined Fits in Interchangeable Manufacture were read by title.

The following selection of the Nominating Committee by the Conference of Local Sections Delegates was approved:

C. K. DECHERD, Meriden, Conn.; W. R. WEBSTER, Bridgeport, Conn., Alternate
J. J. NELIS, Metropolitan; V. M. FROST, Newark, N. J., Alternate
O. P. HOOD, Washington, D. C.; J. G. HATMAN, Philadelphia, Alternate
R. R. JONES, Akron; E. G. BAILEY, Cleveland, Alternate
TOHMAS N. WYNNE, Indianapolis, Ind.; ARTHUR L RICE, Chicago, Alternate
PERLEY F. WALKER, Lawrence, Kan.; W. G. CHRISTY, St. Louis, Mo., Alternate
C. I. CARPENTER, Spokane, Wash.; U. B. HOUGH, Spokane, Wash., Alternate

STUDENT-BRANCH CONFERENCE

A conference of those interested in the work of the Student Branches, at which Prof. W. H. Kenerson presided, was held Wednesday afternoon at three o'clock. Over thirty Student Branches were represented and the attendance was estimated at 100 persons.

Dr. Durand addressed the representatives, urging the students to carry back with them the spirit of the Annual Meeting and a pride in the profession upon which they are just starting. Dr. Tyler reported on the findings of the questionnaire sent to all branches shortly before the meeting and the other members of the Committee spoke. The representatives themselves told of the activities of their individual branches.

EXCURSIONS

The feature excursion of the Meeting was the trip to Lakehurst, N. J., on Friday afternoon December 5, to see the new dirigibles *Los Angeles* and *Shenandoah*. A special train of nine cars carrying 548 people started from New York at 12:25 P.M. and returned by 7:00 o'clock. Opportunity was given to inspect the structure of the ships and to view the operating cabins.

During the week visits were made to the Sherman Creek Station of the United Electric Light & Power Company, the oil-engine-driven electric locomotive which was undergoing tests in the Long Island yards, the new Hudson Avenue Station of the Brooklyn Edison Company, and the Bayway Refinery of the Standard Oil Company of New Jersey.

EVENTS FOR THE LADIES

A little out of the groove of the usual Annual Meeting features for the ladies was a luncheon in the Blue Room of the McAlpin Hotel on Tuesday, attended by 160 women. The unusual feature lay in the addresses given after the luncheon by women who had attended the World Power Conference in England during the summer.

Mrs. C. W. Barnaby, President of the Woman's Auxiliary, presided and introduced the speakers. Mrs. Fred R. Low told in an interesting manner of the trip over on the *Scythia* in June and the various entertainment features on board. Mrs. Lillian Gilbreth spoke from the point of view of one who was primarily interested in the technical features of the sessions at Wembley and at Prague, where she attended the First International Management Conference, presiding at one of its sessions.

Mrs. J. W. Roe told about her trip to Czechoslovakia after the World Power Conference was over, and Mrs. Roy Wright spoke in like manner of Poland.

In addition to the luncheon the ladies enjoyed a Get-Together meeting on Monday evening on the eleventh floor of the building, at which there was a program of music.

Visits were made to a number of points of interest in New York and to Pratt Institute in Brooklyn. On the visit to Pratt, Mrs. James W. Nelson entertained the party at luncheon at her home. A large party inspected the steamship *Olympic* on Thursday afternoon.

Oil Handling and Storing

JAMES A. SHEPARD, Member of the Executive Committee of the Materials Handling Division, presided at the Session on Oil Handling and Storing held under the auspices of the Materials Handling Division on Tuesday morning, December 2.

The only paper of the Session was that by C. G. Sheffield and H. H. Fleming, on The Storage and Handling of Fuel Oil in Industrial Plants, which appeared in the Mid-November issue of MECHANICAL ENGINEERING. The paper provoked considerable

HUDSON AVENUE STATION OF THE BROOKLYN EDISON CO.

discussion, which was participated in by Harold T. Moore, O. P. Hood, William Osborne, M. M. Oakley, A. A. Cary, H. L. Eckersen, and Chairman Shepard. The discussion will appear more fully in a later issue of MECHANICAL ENGINEERING.

Research in Machine Design and Operation

B. H. BLOOD, Chairman of the Research Committee on Cutting and Forming of Metals, presided at the Session on Research in Machine Design and Operation held on Tuesday morning, December 2, under the auspices of the Research Committee on Cutting and Forming of Metals and the Machine Shop Practice Division.

In presenting his paper entitled Comparison of Herbert Pendulum Hardness Tester with Other Hardness Testers, Prof. J. O. Keller called attention to a necessary correction in his paper which appeared in the Mid-November issue of MECHANICAL ENGINEERING. This correction related to his figures for the comparative measurement of hardness with the Rockwell machine. These corrections are given in full on page 73.

Discussion on Professor Keller's paper treated various problems of machinability and measurement. Prof. O. W. Boston[1] described a new British hardness testing machine employing the Brinell principle. Stanley P. Rockwell[2] pointed out that the revised figures of hardness as measured by the Rockwell machine made the Rockwell data consistent with the data obtained with other forms of hardness-measuring devices. A. H. d'Arcambal[3] discussed the relative merits of hardness-testing machines in the shop, and A. V. deForest[4] gave the results of magnetic determinations of

[1] University of Michigan, Ann Arbor, Mich. Mem. A.S.M.E.
[2] Hartford, Conn. Mem. A.S.M.E.
[3] Metallurgist, Pratt & Whitney Co., Hartford, Conn.
[4] American Chain Co., Bridgeport, Conn.

Annual Meeting Committees

Committee on Meetings and Program

JOSEPH W. ROE, *Chairman*
L. B. MCMILLAN
C. N. LAUER
E. HOWARD REED
R. M. GATES

Sub-Committees for 1924 Annual Meeting

C. P. BLISS, *General Chairman*

Reception

PROF. JOHN P. KOTTCAMP, *Chairman*
DR. A. A. ADLER, *Vice-Chairman*
J. W. COX, JR.
A. D. BLAKE
WILLIAM B. CORNELL

Information

E. FEZANDIE, *Chairman*
ALBERT J. SICREE, *Vice-Chairman*
ERNEST BRAMBLE

Courtesy

B. C. MCCLURE, *Chairman*
ROSWELL MILLER
S. H. LIBBY
GEORGE F. FELKER
L. B. MCMILLAN
GEORGE I. RHODES

Excursions

L. H. WELLING, *Chairman*
G. H. GAUS
W. C. HOLMES
W. A. NELSON
R. L. ROBINSON
M. E. RUPP
F. M. SHUMATE
R. A. WRIGHT

Open House

L. F. LYNE, JR., *Chairman*
C. J. BAILEY, *Vice-Chairman*
J. J. EHRHARDT
H. S. SCHANCK
J. P. KOTTCAMP
V. M. FROST
L. B. MCMILLAN
H. L. FREAS
R. S. AUSTIN
R. F. JACOBUS
K. B. MILLETT
K. L. MARTIN

President's Reception

FREDERICK A. SCHEFFLER, *Chairman*
JOHN H. LAWRENCE
W. N. DICKINSON
EDWARD VAN WINKLE
V. M. FROST
R. J. S. PIGOTT

Dinner

R. V. WRIGHT, *Chairman*
W. S. FINLAY, JR.
CLARKE FREEMAN
DR. HAZEN G. TYLER
R. M. GATES
Assisted by
JOHN H. LAWRENCE
CLYDE R. PLACE
SAMUEL H. LIBBY
PETER JUNKERSFELD
W. H. WINTEROWD
K. H. CONDIT
J. J. NELIS
RICHARD S. AUSTIN
ALPHONSE A. ADLER
A. C. TOWNSEND
GEORGE F. FELKER

Catering

JAMES D. TAYLOR, *Chairman*
WILLIAM W. DOWNEY, *Vice-Chairman*
ROBERT JOHNSON
WARREN LEWIS

Ladies' Committees

MRS. RICHARD S. AUSTIN, *General Chairman*
MRS. ROY V. WRIGHT, *Chairman, Acquaintanceship*
MRS. CHAS. TRUMP OWENS, *Chairman, Excursions*
MRS. G. L. KNIGHT, *Chairman, Luncheon*
MRS. G. R. TUSKA, *Chairman, Reception and Tea*

various specimens tested by Professor Keller. This discussion will be recorded more fully in a later issue of MECHANICAL ENGINEERING.

The second paper of the morning was a Preliminary Progress Report of the American Society of Mechanical Engineers Special Research Committee on Metal Springs. In presenting this Report, which was printed in the Mid-November issue of MECHANICAL ENGINEERING, Joseph K. Wood, Chairman of the Committee, stated that the purpose of the Committee was to determine the status of the metal-spring art and to conduct the research necessary to place the design of springs on a more authoritative basis. A. V. deForest pointed out that the mechanical hysteresis of a spring can be followed magnetically. The redistribution of internal stress in a steel caused by any mechanical force is marked by a magnetic change which can be easily measured.

Textile Session

GEORGE H. PERKINS, Vice-Chairman of the Textile Division, presided at the Textile Session, held under the auspices of the Textile Division, on Tuesday morning, December 2.

The papers presented at this Session were The Development of the Spinning Frame, by Robert E. Naumburg, and The Engineer's Field in Industrial Economics, by Eugene Szepesi. Both of these papers appeared in the Mid-November issue of MECHANICAL ENGINEERING. Mr. Szepesi's paper was very fully discussed and the discussion will be reported in a later issue of MECHANICAL ENGINEERING.

General Session

THE General Session, comprising papers of interest to several phases of mechanical engineering, was held Tuesday morning, December 2, with W. H. Kenerson, Vice-President of the Society, in the chair.

R. Eksergian presented his paper on The Strength and Proportions of Wheels, Wheel Centers, and Hubs by title. This paper outlined an approximate analysis of the strength of wheel centers more particularly as applied to spoked locomotive driving wheels.

The second paper, by H. Loring Wirt, was entitled The Turbine Designer's Wind Tunnel. Mr. Wirt's paper, which appears in abstract in this issue of MECHANICAL ENGINEERING, describes air-testing methods developed by the General Electric Company for testing elements of turbines, such as nozzles, exhaust hoods, etc. by simulating the conditions in the turbine and determining the effect on models of these elements. In the discussion G. B. Warren[1] pointed out that in connection with the work Mr. Wirt described, extensive nozzle-reaction tests with steam rather than with air had been carried on which had been supplemented by extensive series of steam-turbine tests using a comparatively large steam turbine in which different types of nozzles and buckets could be used. The air methods explained by Mr. Wirt were far cheaper than any other method but the results obtained in the air tests were checked by use with steam. Prof. A. G. Christie[2] pointed out the importance of the "preliminary conditions" in a nozzle test. Prof. F. O. Ellenwood[3] asked what was the effect of scale size of models on test results, whether duplicate tests on the same model gave close check results, whether tests had been made with air carrying a spray of water, whether or not less pressure drop was to be expected in air or steam lines having short turns instead of rounded ones if the apparent superiority of the square corner over the round corner was true, and whether the apparatus could be adapted to test moving blades. Dr. Harvey N. Davis[4] expressed the opinion that a similar method of testing to that used by Mr. Wirt would result in a decrease of losses in locomotive blowers, in superheaters, and through the throttle valves of locomotives.

In his closure Mr. Wirt restated the superiority of the square corner in steam lines over a round corner. The advantage decreased as the radius of the average cross-section of the turn was increased. The superiority of the square corner particularly disappeared when the radius of the turn was three or four times the diameter of the pipe. In answering Professor Ellenwood's questions, Mr. Wirt stated that scale size had no effect because the testing was used to compare nozzles of present construction with nozzles of a new construction and as these two models would be in a similar scale, the results could be compared correctly. He said that there was no difficulty in checking final efficiency of the nozzle within a tenth of one per cent in duplicate tests on the same nozzle. Some work was being done with moisture in the models. He answered the question of adapting the apparatus to make tests on moving blades by stating that conditions of motion in the blade were simulated by making the angle of approach to the bucket the same as the angle of approach to

[1] General Electric Co., Schenectady, N. Y.
[2] Prof. M. E., Johns Hopkins University, Baltimore, Md. Manager A.S.M.E.
[3] Prof. Heat Power Engineering, Cornell University, Ithaca, N. Y. Mem. A.S.M.E.
[4] Prof. M. E., Harvard University, Cambridge, Mass. Mem. A.S.M.E.

the bucket in the steam turbine. Nozzle action and bucket action, he said, could not be tested separately.

The final paper of the session, by Prof. L. V. Ludy, was entitled Test of a Prosser-Type Reciprocating Engine. An abstract of this paper with a running account of the discussion will appear in a later issue of MECHANICAL ENGINEERING.

Joint Session with the A.S.R.E.

GEORGE A. HORNE, President of the A.S.R.E., was the presiding officer at the joint session held on Tuesday afternoon, December 2. The first paper was by W. H. McAdams, who discussed Some Factors Influencing Friction, Velocity Distribution, and Heat Transmission for Fluids Flowing Inside Pipes. This paper will appear in a later issue of *Refrigerating Engineering*, the Journal of the A.S.R.E. An abstract with a brief account of the discussion will appear in a later issue of MECHANICAL ENGINEERING.

Victor J. Azbe's paper on Water-Cooling-System Efficiency was the second to be presented, and a report of the discussion will appear in a later issue of MECHANICAL ENGINEERING, together with an abstract of the third paper of the afternoon, by W. H. Carrier and D. C. Lindsay, on The Temperatures of Evaporation of Water into Air.

Machine Shop Practice Session

F. O. HOAGLAND, of the Executive Committee of the Machine Shop Practice Division, presided at the session held under the auspices of this Division on Tuesday afternoon, December 2.

The first paper, on The Effect of Inaccuracy of Spacing on the Strength of Gear Teeth, by Messrs. L. J. Franklin and Charles H. Smith, was presented by Mr. Smith. The discussion related to the fundamental conditions under which the experiments were conducted and the forms of gears used in the test. A number of questions were asked which required time for reply, and the final account of the discussion will appear in a later issue of MECHANICAL ENGINEERING.

Mechanical Springs was the title of a paper by Joseph Kaye Wood. In the discussion Fritz Loeffler[1] suggested that Mr. Wood consider the formula covering the oscillations in springs in extending the general method of spring design outlined in his paper. J. W. Rockefeller[2] emphasized the fact that difficulties in spring design were due to the fact that springs had been viewed from the standpoint of some particular type rather than in a general way. Proper progress in spring research would be made only when the broad importance of the subject was realized. He emphasized the need for understanding the term "hysteresis" by all who used it. In his closure Mr. Wood stated that it would be a simple matter to extend the general method of design to include a formula for the period of oscillation. He agreed with Mr. Rockefeller that hysteresis was an important question, especially in sensitive length-measuring machines and in precision-weighing machines.

A paper on Ruling Line Standards, by Herbert B. Lewis and C. G. Peters and presented by Mr. Lewis, appeared in the Mid-November issue of MECHANICAL ENGINEERING. After a number of questions regarding details of operations had been answered by Mr. Lewis, B. H. Blood[3] presented a discussion in which he pointed out that pressure contact was an important matter in fine measuring machines, especially in measuring a hollow cylinder where a slight variation in pressure would affect the accuracy of comparative readings. He pointed out that the instrument mentioned by Mr. Lewis was a laboratory or super-inspection instrument rather than a machine to be placed in the average tool room. Its value was great, however, in a shop where reference standards were needed and fine comparisons had to be made. Mr. Blood stated that by a delicate sense of touch which had been developed among tool makers, many men were able to distinguish a variation between two surfaces merely by screwing the micrometer down to them, and that by this sense of touch differences of a hundredth thousandth of an inch

[1] Techno-Service Corp., New York, N. Y.
[2] Engr., John Chatillon & Sons, New York, N. Y. Jun. A.S.M.E.
[3] Genl. Mgr., Pratt & Whitney Co., Hartford, Conn. Mem. A.S.M.E.

might be detected. Albert Kingsbury[1] related his experiences using a spherometer made in bar form instead of in the usual circular form, by which it was possible to develop a sensitivity as great as one to two millionths of an inch. Dr. G. M. Bond[2] was called upon to tell of the pioneer work in accuracy measurements and especially in dividing linear standards into their component parts. Fred J. Miller[3] emphasized the fact that in order to determine whether two things were exactly the same size by any sense of touch that might be applied, not only must the surfaces be clean but the finish on those surfaces must be of the same quality. He also indicated that a difference in contact between two flat surfaces of considerable area and the difference between a flat surface and a cylindrical surface would make an appreciable difference, in view of the fact that metals were elastic and that they yielded in proportion to the load. In his closure Mr. Lewis stated that the machine he had described was used in the gage department and not in the shop. He also stated that by a little experience in handling the machine air films between the blocks could be removed and consistent measurements obtained.

Turbo-Locomotive Session

THE Turbo-Locomotive Session was held under the auspices of the Railroad Division on Tuesday Afternoon, December 2, with William Elmer, Vice-Chairman of the Division, presiding.

Two papers gave the results of foreign experience in turbine locomotives. Dr. H. Zoelly provided a paper on the Zoelly Turbine-Driven Locomotive, and Messrs. George F. Jones and T. Laurence Hale contributed another on The Ramsay Condensing Turbo-Electric Locomotive. Both of these papers were presented by A. F. Stuebing, Secretary of the Railroad Division.

The discussion treated of the relative merits of turbine locomotives and electric locomotives, and dealt with the limitations which must be overcome if turbine locomotives are to be successfully applied to American practice. A more complete account of the discussion will appear in a future issue of MECHANICAL ENGINEERING.

Dr. Zoelly's paper was printed in pamphlet form and abstracted in the November issue of MECHANICAL ENGINEERING. The manuscript of the Ramsay Locomotive was received only a few days before the meeting, and will appear in a later issue of MECHANICAL ENGINEERING.

Public Hearing on Power Test Codes

PRESIDENT Fred R. Low, as Chairman of the Main Committee on Power Test Codes, presided at the public hearing convened on Tuesday afternoon, December 2, at which the Power Test Codes for Solid Fuels, and Gas Producers were presented for criticism. The public hearing is a regular step in the A.S.M.E. procedure of setting up Test Codes. Comments made at the hearing are referred back to the Committee that prepared the Code for consideration before submission to the Main Committee, and then the codes are sent to the Council for final adoption.

Session on Oil Burning

ON WEDNESDAY morning December 3, the Session on Oil Burning was held under the joint auspices of the Fuels and Power Divisions, with E. H. Peabody in the chair. The program included three papers which had previously been printed in the Mid-November issue of MECHANICAL ENGINEERING.

The first paper was by H. G. Donald, Lieut-Comdr. U. S. N., on Fuel-Oil Burning in the United States Navy. Nathan E. Lewis told of Oil Burning in Industrial-Plant and Central-Station Service, and H. E. Newell outlined the Hazards of Industrial Oil Burning. The discussion was very complete and interesting and will be published fully in a later issue of MECHANICAL ENGINEERING.

[1] Kingsbury Machine Works, Greenwich, Conn. Mem. A.S.M.E.
[2] Hartford, Conn. Past-Vice-President A.S.M.E.
[3] Member, Public Service Commission of State of Penna. Past-President A.S.M.E.

Session on Lubrication

THE Special Research Committee on Lubrication and the Machine Shop Practice Division coöperated in a Session on Lubrication held on Wednesday morning, December 3, with Albert Kingsbury, Chairman of the Special Research Committee on Lubrication, presiding.

The three papers which were presented were thoroughly discussed. They will appear in abstract with the discussion in a later issue of MECHANICAL ENGINEERING. The titles and authors of the papers are as follows: An Investigation of the Critical Bearing Pressures Causing Rupture in Lubricating-Oil Films, by Lieut-Com. Leonard N. Linsley, U.S.N.; High-Pressure-Bearing Research, by Louis Illmer, and A Graphical Study of Journal Lubrication (Part II), by H. A. S. Howarth.

National Defense Session

ASSISTANT Secretary of War Davis presented his address on The Engineering of National Defense at the Session on National Defense held under the auspices of the National Defense Division on Wednesday morning, December 3. Colonel Davis' address appears on another page of this issue of MECHANICAL ENGINEERING. Fred J. Miller, Chairman of the National Defense Division, presided over the Session, at which there were also three other interesting technical discussions.

Major J. B. Rose presented a paper on Some Problems in the Design of Ordnance, which appeared in the Mid-November issue of MECHANICAL ENGINEERING. In the discussion Pliny E. Holt[1] advocated the policy of dependence upon a commercial type of tractor rather than a special military design, on the assumption that militarization of artillery was necessary. R. L. Goetzenberger[2] discussed Major Rose's paper from the point of view of the designer of fire-control apparatus. He pointed out the important points that must be considered in sighting systems and data computers. He also indicated the severity of the problem of anti-aircraft defense.

The second technical paper, by Colonel T. C. Dickson, told of the progress of examination of metals by X-rays at the Watertown Arsenal. Colonel Dickson's presentation, an abstract of which appeared in the Mid-November issue of MECHANICAL ENGINEERING, was very fully illustrated by lantern slides.

Dr. F. C. Langenberg then presented a paper on New Developments in Gun Construction. This paper will appear in a later issue of MECHANICAL ENGINEERING.

In the discussion of these two latter papers, A. V. deForest pointed out that magnetic inspection of stress relations gave results very close to those obtained by X-ray examination of metals. I. E. Moultrop[3] testified to the value of X-ray examination of metals in connection with the 1200-lb. boiler being installed at the Weymouth plant in Boston, in which examination by X-rays showed a flaw in casting which examination of the outside could not reveal. Samuel L. Hoyt[4] reviewed the information which had been obtained in metallurgical analysis by means of the X-ray.

Mechanical Design for Safety

C. B. AUEL, President of the National Safety Council, presided at the Session on Mechanical Design for Safety held Wednesday morning, December 3, under the joint auspices of the American Society of Safety Engineers, the Engineering Section of the National Safety Council and the A.S.M.E. Committee on Safety Codes.

The first paper, on The Hazards of Pulverized Fuel Systems, prepared by H. E. Newell and Robert Palm, was presented by Mr. Palm. This paper appeared in the Mid-November issue of MECHANICAL ENGINEERING. The discussion brought out excellent statements of the importance of care, judgment, and good housekeeping necessary in pulverized-fuel operation. It will be reported fully in a subsequent issue of MECHANICAL ENGINEERING.

Lewis A. DeBlois presented a paper at this session entitled A Place for Safety, which appears in full in this issue of MECHANICAL ENGINEERING.

Progress in Steam Research

DR. A. M. GREENE, JR., member of the Executive Committee of the Steam Table Fund, presided at the session devoted to Progress in the Steam Table Research on Wednesday afternoon, December 3. Geo. A. Orrok, Chairman of the Committee, presented a brief financial report after which Dr. R. V. Kleinschmidt related the progress that had been made at Harvard University in the work that is being carried on there under the charge of Dr. Harvey N. Davis. Dr. F. G. Keyes explained the apparatus that was being developed at the Massachusetts Institute of Technology, and was followed by Nathan S. Osborne, of the Bureau of Standards, who presented a progress report of the work being carried on by Mr. Stimson and himself at the Bureau of Standards. Dr. Harvey N. Davis presented a discussion of the data already secured from the Joule-Thomson experiments at Harvard.

A paper by Nathan S. Osborne on The Direct Measurement of Heat Content of Superheated Steam, which appeared in the Mid-November issue of MECHANICAL ENGINEERING, was presented by title, and the Chairman requested that those who wished to discuss it submit their comments in writing to the headquarters of the Society. The February issue of MECHANICAL ENGINEERING will carry the complete statements of the progress being made by the investigators in the properties of steam.

Education and Training for the Industries of Non-College Type

ON WEDNESDAY afternoon, December 3, the Committee on Education and Training for the Industries sponsored a session under the chairmanship of Prof. John T. Faig. The program consisted of three addresses. Magnus W. Alexander, managing director of the National Industrial Conference Board, spoke on Industry's Interest in Industrial Training, and George B. Thomas, Educational Director, Western Electric Company, dealt with the subject of industrial education, and presented A Summary of the Work of the American Management Association and Its Predecessors. The final speaker was H. A. Frommelt, Apprentice Supt. of the Falk Corpn., of Milwaukee, who told of the Need for District Organization of Modern Apprenticeship. These addresses will appear in a future issue of MECHANICAL ENGINEERING.

Aeronautic Session

DR. SANFORD A. MOSS, Chairman of the Aeronautic Division, presided at the Aeronautic Session which was held on Thursday morning, December 4. The first paper to be presented was one dealing with the Equipment Used for Aerial Surveying, by Ernest Robinson. Mr. Robinson's paper will appear in a later issue of MECHANICAL ENGINEERING.

The second paper, by Prof. Alexander Klemin, was entitled An Introduction to the Helicopter. Professor Klemin gave a review of the aerodynamics and construction data thus far available, described a number of modern helicopters, and pointed out lines of development open and possible uses. The discussion centered about the use of the helicopter and was very interesting. It will appear in a later issue of MECHANICAL ENGINEERING.

The final paper of the session, by Edmund Burke Carns, dealt with Production Airplanes of Metal. This paper covered the entire construction of a metal biplane as well as the cost of its production in lots of from one to ten. In the discussion the relation of production cost to economical design was gone into fully. A later issue of MECHANICAL ENGINEERING will contain an extended account of the discussion together with the closure of the author. The papers by Messrs. Klemin and Carns appeared in the Mid-November issue of MECHANICAL ENGINEERING.

Steam Power Session

THE Steam Power Session on Thursday morning, December 4, held under the auspices of the Power Division, was presided over by N. E. Funk, Chairman of the Division. The attendance at

[1] Holt Mfg. Co., Stockton, Cal. Mem. A.S.M.E.
[2] Frankford Arsenal, Frankford, Pa. Mem. A.S.M.E.
[3] Boston Edison Co., Boston, Mass. Mem. A.S.M.E.
[4] Research Laboratory, General Electric Co., Schenectady, N. Y.

the session filled the auditorium, and the discussion of the four papers lasted through the morning and made an adjourned session necessary.

The papers presented were: Water Treatment for Continuous Steam Production, by R. E. Hall; The Increase in Thermal Efficiency Due to Resuperheating in Steam Turbines, by W. E. Blowney and G. B. Warren; A Review of Recent Applications of Powdered Coal to Steam Boilers, by Henry Kreisinger; and Recent Developments in the Burning of Anthracite Coal, by W. A. Shoudy and R. C. Denny. The discussion at the session will be reviewed carefully and abstracted in a later issue of MECHANICAL ENGINEERING.

Management Session

ROBERT T. KENT, Chairman of the Management Division, presided at the Session on Management which was convened on Thursday morning, December 4. This session was a joint meeting of the Management Division of the A.S.M.E. and the Taylor Society.

L. P. Alford presented the following resolutions of appreciation for Frank B. Gilbreth, which were unanimously adopted by those present:

WHEREAS, Frank Bunker Gilbreth has passed to his reward; and

WHEREAS, He was a member of this Society for twenty-one years, a faithful attendant at its meetings, and an illuminating contributor to its proceedings, a member of the executive committee of the Management Division; and

WHEREAS, He was an active worker for international good-will and for mutual esteem between engineers of many countries; and

WHEREAS, He was a devoted husband and father, a loyal friend, a passionate protagonist of his adopted causes, and justly was called thought detonator to many groups; and

WHEREAS, He was a scientist of rare attainment, evidenced by his work and writings on construction, his allegiance to scientific management, his painstaking development of an ultra-refined technique for the study of mechanical and human motion, his faithful search for all knowledge in his fields of interest and his scientific application of mechanical principles to the reconstruction and vocational training of the disabled; and

WHEREAS, His reticence concerning his consulting practice was an example to all consultants, his vigorous, witty attack an example to all disputants, and his breadth of human interest an example to all engineers, therefore, be it

Resolved, That copies of these resolutions be sent to his family, placed in the Society's records, and sent to the technical press.

The first paper discussed at the meeting was Fred. W. Taylor's paper on Shop Management, originally presented before the Society in 1903. The paper is now of age and it is a unique compliment to both paper and author that it was re-presented in its original form twenty-one years after its first presentation.

Morris L. Cooke[1] made the presentation by reading extracts from the paper. There was a large amount of written discussion by leaders in the management field which will be reviewed carefully for a future issue of MECHANICAL ENGINEERING.

The final paper for the session, by Sanford E. Thompson and H. T. Rollins, dealt with the Development of a Modern Hosiery Plant, and was presented by Mr. Thompson and Miss Hazel Moore who represented Mr. Rollins. This paper appeared in the Mid-November issue of MECHANICAL ENGINEERING.

Session on Management and Machine-Shop Practice

RICHARD A. FEISS, President of the Taylor Society, acted as chairman of the session on Management and Machine Shop Practice which was held under the joint auspices of the A.S.M.E. Management Division, the Machine Shop Practice Division, and the Taylor Society.

George D. Babcock presented a paper on Production Control, and Ralph E. Flanders one on the Design, Manufacture, and Production Control of a Standard Machine. Mr. Flanders' paper appeared in the December issue of MECHANICAL ENGINEERING. An abstract of Mr. Babcock's paper with an account of the discussion at the session will appear in a later issue of MECHANICAL ENGINEERING.

[1] Consulting Engr. in Management, Philadelphia, Pa. Mem. A.S.M.E.

Oil and Gas Power

AN ENTHUSIASTIC audience was present on Thursday afternoon, December 4, at the Session on Oil and Gas Power held under the auspices of the Oil and Gas Power Division. Elmer A. Sperry, Chairman of the Division, presided. Three important papers were presented which will appear in abstract with the discussion in a future issue of MECHANICAL ENGINEERING. The titles and authors of the papers were Solid-Injection Oil Engines, by R. Hildebrand; Large Oil Engines, with Special Reference to the Double-Acting Two-Cycle Type, by Charles E. Lucke; and Gas Turbines, by Lionel S. Marks and M. Danilov.

Hydraulic Session

THE Hydraulic Session was held on Thursday afternoon, December 4, under the auspices of the Power Division, with William F. Uhl acting as chairman.

In the absence of the author, Lewis F. Moody presented a paper by H. L. Doolittle entitled A Method for the Economic Design of Penstocks. The discussion, which was extended, centered largely upon the effect of water hammer on penstock design. An abstract will appear in a later issue of MECHANICAL ENGINEERING.

The second paper of the session related to Intakes for Power Plants and was presented by Prof. Robert W. Angus.

The Power Show

THE Third National Exposition of Power and Mechanical Engineering, held in the Grand Central Palace, New York City, December 1 through December 6, was visited by 79,521 engineers, manufacturing executives, operating men, students, and quite a few ladies. Over 380 exhibits filled the first two floors and partially occupied the third floor of the Palace. The exposition covered the field of power quite fully and also included excellent examples of exhibits in other fields of mechanical engineering, such as handling materials, mechanical power transmission, machine tools, heating and ventilating, and refrigeration. In general the exhibits were featured by working models or by full-sized apparatus in operation. Eight lectures on important developments in the various phases of power and mechanical engineering were held. These were supplemented by an unusually attractive program of motion pictures. The National Museum of Engineering and Industry had an excellent showing of historical engineering matter.

Boiler Code Committee at Annual Meeting

THE December meeting of the Boiler Code Committee, which was held on Monday, December 1, proved to be a gathering center for those interested in the boiler industry. A number of visitors to the Annual Meeting who have been interested in the activities of the Boiler Code Committee were present by invitation and participated in the discussion of the regular interpretation service, to which the meeting was devoted.

This meeting was one of great importance in one respect, as it marked the completion of the work of formulating the Code for Unfired Pressure Vessels which had been in process of preparation for a number of years. The Final Report of the Sub-Committee to which this Code had been entrusted was published in the December issue of MECHANICAL ENGINEERING and the Report as presented in this form was examined and proofread. An adjourned meeting of the Committee was held on Wednesday, to confer with representatives of the American Society of Refrigerating Engineers and of the American Welding Society, at which, after a few typographical corrections and minor changes had been authorized, the Report was approved and commended.

Technical Committee Meetings

THE numerous technical committees of the Society took advantage of the presence in New York of a considerable number of their members during Annual Meeting week and held 19 committee meetings. Most of these meetings were worked in

(*Continued on page 77*)

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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An Ideal Engineering Meeting

What are the features that make the meeting of a body like The American Society of Mechanical Engineers useful, satisfying, and successful?

One such factor is the opportunity afforded for social and professional intercourse, for the stimulus of contact, the forming of acquaintanceships, the enjoyment and cementing of existing friendships, the broadening of one's vision and the excitation of one's mental processes by hours spent in the company of the thinkers of the profession and in an atmosphere of intellectual progressiveness.

These things make the difference between being at a meeting and reading about it.

The atmosphere of good fellowship and sociability that prevailed at the Annual Meeting last month and was so much remarked upon, added without doubt to the enjoyment of the meeting, particularly by the newer members. And it all came about so naturally and spontaneously. The "get together" on the first evening when shop and technicalities and professional dignity were put aside for a couple of hours of frolic—good, clean fun at which everybody could laugh together and in which everybody was urged to join—was doubtless instrumental in bringing this about.

And this spirit of professional good fellowship was brought to a climax in the dinner of Wednesday evening which so well effected its purpose of impressively initiating the newly elected members into the Society. Pitched upon a high plane, with a lucid setting forth of the traditions, purposes, and possibilities of the Society, and how these possibilities can best be furthered and the advantage that the Society offers realized by the membership, followed by an inspiring address of general appeal, it not only impressed the new member that he had become a factor in the organized front of a great profession and was one with those who had made it what it is, but brought new enthusiasm to the older guard.

In the old days one came to *the* meeting. There was only one, and there the program was enacted and everybody was present. One saw the Society as an entity. The organized profession as a whole assembled and discussed and considered, and even badgered some of its members.

Now the meeting is split up into a multiplicity of simultaneous sessions, public hearings, conferences, committee meetings, assemblages of section delegates, etc., to the distraction of the attendant tractating to different centers of interest from different directions, and to the prejudice of the solidarity of the Society, the definiteness and magnitude of the conception of it derived by the public and the members. The separate sessions are necessary, interesting, and valuable to those to whom they specially appeal, helpful in carrying out its program of usefulness by the Society, but the tone of the meeting will be higher, the Society bigger and grander in the conception of those who take part in it, if once or twice during the meeting a big, impressive, inspiring audience is drawn together by a lecture of sufficient breadth and general interest to appeal to the whole profession by an authority of such outstanding importance as to lend distinction to the occasion and command general attention. Gestures in this direction were the lectures by Drs. Sears and Bridgman at the last meeting.

Of course the general background must be creditable and adequate; enough, but not too many, papers of real merit, discussed by specialists in their subjects, with plenty of opportunity for the man who "wants to know" to ask questions and suggest further exposition; a forum where one may see and hear and get a first-hand impression of the men of whom he hears and reads in connection with a subject.

I wish that the United Engineering Societies Building had more facilities for comfortable chumming between sessions, for sitting around and visiting, for extending to those in attendance generally the opportunities for social intercourse enjoyed by those who have access to the contiguous Engineers' Club. May not future development profitably be in the direction of giving to this collective home of the great national engineering societies more of the atmosphere of professional fellowship which characterizes the British Institutions than of the directorates and secretariates of great corporations? Our own headquarters are acquiring something of this atmosphere but are inadequate for the social accommodation of such numbers as attend our annual gatherings.

Fred R. Low.[1]

Measuring Economies

The efforts of the A.S.M.E. Materials Handling Division to evaluate the factors involved in the adoption of labor-saving equipment are bearing fruit. In the correspondence columns of this issue of Mechanical Engineering there is evidence that the report of the Committee has received thoughtful consideration. One member brings criticism, to which the Committee presents a reply, and a second member shows how the formulas suggested for selecting labor-saving equipment may also be adapted to the choice of desirable machine tools. The Committee solicits criticisms and suggestions, appreciating that only by widespread discussion can a satisfactory usage be evolved. The Committee further desires that the formulas which were presented in the September, 1923, issue of Mechanical Engineering be applied to many varying cases, so that any limitations may be revealed.

As progress in science and engineering is facilitated by the use of instruments to measure the forces and materials employed, so is the selection of new devices on an economic basis made simple by a means for evaluating and comparing the many factors involved in the decision as to the proper device to select. The formulas in question are being proposed to provide this simple means. However, the problem is far from being a simple one, for in the selection of new equipment there may be intangible factors of increased service or bettered production for which definite money values must be assigned. The question of what constitutes overhead, which is treated in varying ways in various industrial organizations, brings a complication not always easy to eliminate. The formulas, however, do state the various details that must be considered in any decision, and present them in a systematic way that aids analysis, permits evaluation, and provides an answer. The value of the formulas, therefore, must be judged upon the results of the solution of many problems by their use and the consequent agreement with the solution and the performance of the equipment in the years after it is installed. Realizing this thoroughly, the Committee is making haste slowly and applying many severe tests so that the final product of its work will be of value in eliminating mistakes in the choice of equipment which may result in economic waste to both manufacturer and user.

[1] Past-President, A.S.M.E., Editor, *Power*.

Materials under Extreme Temperatures

THE formation of the Joint Committee on the Properties of Materials under Extreme Temperatures by the American Society for Testing Materials and The American Society of Mechanical Engineers is an important step in the search for materials that will maintain strength under critical conditions. The Committee is one result of the joint meeting of the two societies held in Cleveland in May, 1924.

While the scope and program of the Committee's work has not as yet been completely developed, it is obvious that a great deal of laboratory investigation will be required. This must be supplemented, however, by extensive field observation of materials under critical conditions. It is proposed to investigate the effects of very low temperatures on materials as well as those of high temperatures. The high-temperature materials give promise of being of more far-reaching importance, however, considering the aggregate economies that may be obtained by the use of high steam pressures and the corresponding high temperatures. Many processes are now actually limited because higher operating temperatures cannot be used. The project which has been assigned to this Committee therefore has an importance comparable to that of the research into the properties of steam and the study of the effects of fatigue on metals.

Like friction, which in some cases is indispensable, the inability of metals to hold their strength under high temperatures is not an unmixed evil, for it does permit forging and rolling. However, in the steam power station the operating limit of approximately 750 deg. fahr. has been accepted by American designers because of lack of materials trustworthy under higher temperatures. In the oil refinery much higher temperatures are used but constant vigilance is required, especially with valves and fittings, which must be inspected frequently.

The formation of this new committee under the joint auspices of two technical societies to attack such an important problem is merely added evidence that in the sciences and the arts that show true progress, secret processes are of the past. Its purpose is important and its opportunities for service are great. May it be successful.

The Nation's Wood Lot

PRESIDENT COOLIDGE has issued a solemn warning that if our present rates of usage and growth of timber prevail, our forests will be exhausted in forty years. He has pointed out the penalties we are paying for national neglect of the problems of reforestation and timber waste, and called for the administration of our great national resources for the greatest welfare of all the people, both for the present and the future. His address, delivered before the National Conference on Utilization of Forest Products in Washington on November 19, 1924, received wide discussion in the public press, which is a favorable sign that public opinion is being aroused. But mere discussion or an aroused public opinion will avail little unless those who have an intimate contact with timber use can act. This implies proper legislation. The American Engineering Council through its Committee on Legislation is interesting itself in the Clarke-McNary Bill, which is dealt with more fully later in this editorial.

One phase of the timber question is essentially engineering, and that is the reduction of waste in the use of timber. The Forest Service has stated that by known methods nearly thirty per cent of the drain on our forests can be relieved, and eventually it is hoped that this saving can be doubled. The methods of standardization and economy through which these results may be accomplished and the processes of research by which greater savings are possible are already thoroughly familiar to engineers. John W. Blodgett, then president of the National Lumber Manufacturers' Association, in his address before the 1923 Annual Meeting of the A.S.M.E., pointed them out and called for the assistance of mechanical engineers.

But any procedure to reduce the lumber waste can only be supplementary to the fundamental provision of adequate fire protection for growing trees and a proper policy of reforestation. These are matters which may be assisted by national and state legislation in which engineers as citizens should take an interest and exert their leadership. Dean Cooley has expressed his faith that the engineer when aroused will bring to bear a protective hand as great as his creative hand is now. How is this to be done? Secretary Wallace of the American Engineering Council suggests that each local engineering society and each local section of a national society should make a careful study of the Clarke-McNary Bill, investigate the present forestry policy of its state and the state laws relating thereto, draw up a statement of the changes that will have to be made in order for its state to comply with the Clarke-McNary Act, and give publicity to its findings. Further, they should enlist the coöperation of all interested organizations in the campaign and inform their representatives in the House and Senate of their interest in this great problem. As a final step, they should stimulate fire prevention and the utilization of all suitable land for forest production, and develop public support for the organized effort to reduce timber waste.

Mr. Wallace has also made an analysis of the Clarke-McNary Bill and finds its salient points to be as follows:

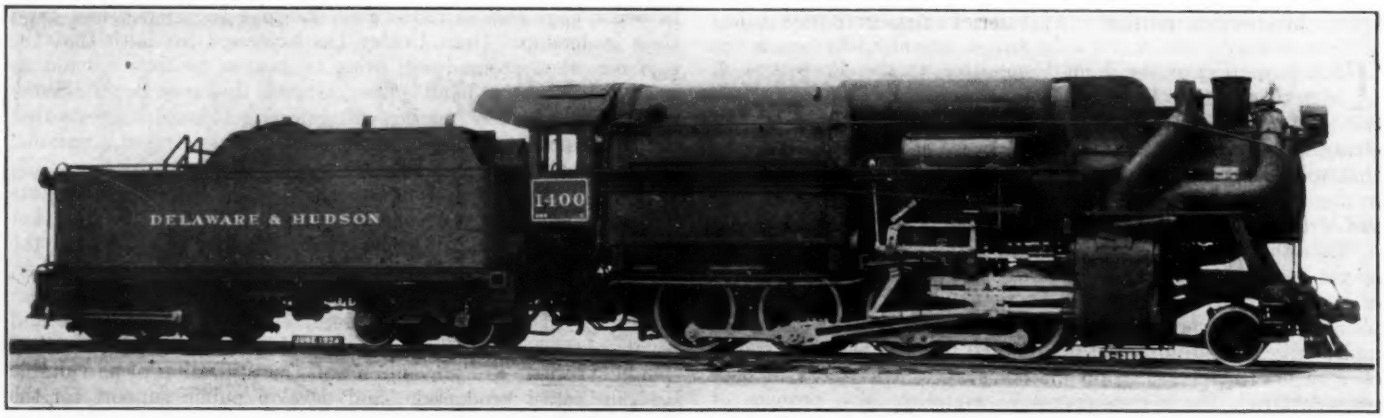
> The intent of the Clarke-McNary Bill is to establish a national forestry policy for the United States, the immediate aim of which is to increase as rapidly as possible the rate of timber production on all land suited to this form of use. A most important feature is the consideration given to the practice of forestry by the individual land owner along with the enlargement of publicly owned forests. One of the purposes of the law is to remove the risks and handicaps from private timber growing in order to give the greatest possible incentive to commercial reforestation.
>
> The bill authorizes the Secretary of Agriculture to coöperate with the states in devising and recommending efficient systems of fire protection so that a nation-wide plan of fire protection may be developed, and to extend the aid of Federal funds to the states in carrying out their protection systems; funds to be matched dollar for dollar; recognition being given to money spent by private land owners for protection. It provides an annual appropriation of $2,500,000 for carrying out a nation-wide plan of protection, of which the Secretary of Agriculture may spend such amount as he deems advisable for a study of tax laws applying to land growing timber crops and for developing methods of insuring standing timber and growing forests. The annual property tax is not adapted to timber crops and may largely defeat private reforestation. A rational adjustment of taxation must be made.
>
> The bill further authorizes Federal coöperation with states in the procurement and distribution of forest-tree seeds and plants and in establishing and renewing wood lots, shelter belts, and other valuable forest growth. It looks to the extension of National Forests ownership in areas where special public interests or responsibilities are involved—like the protection of navigable waterways, and provides for bringing under forest management all the timber-growing lands which the Government now owns.
>
> It amends the Weeks Law by authorizing the purchase of forest lands for timber production as well as for protection of navigable streams so long as the land is within an important watershed. It authorizes the Secretary of Agriculture to accept gifts of land chiefly valuable for timber crops, subject to certain reservations. It authorizes the survey and classification of vacant public lands which could be incorporated in the National Forests; and it authorizes the President to create National Forests covering the portions of military and other public reservations suitable for timber production, when this form of use will not conflict with the needs for which the reservations were established.
>
> The Act does not deal with the controversial question of public regulation of timber cutting on privately owned land.

William H. Bassett—1925 James Douglas Medalist

THE James Douglas gold medal for distinguished achievement in non-ferrous metallurgy has been awarded for the year 1925 by the American Institute of Mining and Metallurgical Engineers to William H. Bassett, technical superintendent and metallurgist of the American Brass Company. Mr. Bassett has been engaged in the brass industry since 1902 and is regarded as its pioneer metallurgist. He has done original work in the standardization of methods of chemical analysis of copper and its alloys, in the improvement of condenser tubes and their methods of manufacture, in the "season" cracking of brass and its prevention, and in the preparation of standard specifications for non-ferrous metals and their alloys.

The High-Pressure Steam Locomotive

ON DECEMBER 4, 1924, the new high-pressure compound steam locomotive built by the American Locomotive Company for the Delaware & Hudson Company was christened the



THE "HORATIO ALLEN"—TWO-CYLINDER COMPOUND LOCOMOTIVE OPERATING UNDER 350 LB. PRESSURE AND DEVELOPING 84,300 LB. TRACTIVE EFFORT WITH A FACTOR OF ADHESION OF 3.54

"Horatio Allen" in honor of Horatio Allen who set up and operated the "Stourbridge Lion," a locomotive imported from England by the Delaware & Hudson Company in 1829. The ceremony was performed at Colonie, near Albany, New York, in the presence of a large group of railway officials. This engine, whose picture is shown above, represents a great stride forward in the strenuous efforts that are being made to increase the economy of the steam locomotive.

It is built to operate at 350 lb. boiler pressure and either as a compound or simple engine. The maximum tractive power is 84,300 lb. when operating as a simple engine and 70,300 lb. when operating as a compound engine. The booster under the tender provides 19,700 lb. when operating at 250 lb. pressure.

The adhesion factor when operating as a simple engine is 3.54, and when operating as a compound, 4.24. The total weight of the engine without tender is 348,000 lb.; the tender when loaded with $15^1/_4$ tons of coal and 9000 gal. of water weighs 197,800 lb. The cylinder diameters are $23^1/_2$ in. for the high-pressure and 41 in. for the low-pressure; the stroke is 30 in. The total wheelbase of engine and tender is 65 ft. $7^3/_4$ in.

In his address at the christening ceremony L. F. Loree, president of the Delaware & Hudson Company, stated that the new locomotive was capable of developing one-third more power with a decreased consumption of fuel and water of one-third as compared to the most economical of the consolidation locomotives of the Delaware & Hudson Company.

December Meeting of the A.E.S.C.

THE regular quarterly meeting of the American Engineering Standards Committee was held December 11 at the Engineers' Club, New York.

The announcement of the result of the letter ballot for the election of the officers for 1925 showed that Charles E. Skinner, assistant director of engineering, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., was elected chairman of the Main Committee and Charles R. Harte, construction engineer of the Connecticut Company, New Haven, Conn., vice-chairman.

Following a custom established by former Chairman A. W. Whitney, the Committee discussed for a brief period one phase of the general problem of standardization. F. L. Rhodes led the discussion with a brief paper on standardization in the telephone industry. He stressed the importance of national standardization, but reminded the Committee that the standards which are developed under its procedure should in most cases be "dynamic" and not "static." His remarks, which were enthusiastically received and thoroughly discussed by those present, will be made available to any who are especially interested. Dr. P. G. Agnew, Secretary of the Committee, reported the results of recent letter ballots, one of which approved the revision of a Safety Code for Power Presses developed under the sponsorship of the National Safety Council.

The Finance Committee submitted a budget for the coming year totaling \$53,000, of which it expects to receive \$20,000 from membership dues and \$27,300 from sustaining members. It will start the year with a cash balance of approximately \$5700.

The Special Committee directing the coöperation with the Federal Specifications Board made its quarterly report, in which it indicates that a considerable number of specifications developed by the F.S.B. have been circulated through the channels of the A.E.S.C.

It was reported that former Chairman Whitney was on his way to Lima, Peru, to attend the first Pan-American Standardization Conference. Mr. Whitney is attending this conference as one of the three official delegates of the United States, and carries credentials from the A.E.S.C. and many of its member bodies.

In its report the Mining Standardization Correlating Committee recommended the organization of four sectional committees as follows:

1 Code for Rock Dusting, with the American Institute of Mining and Metallurgical Engineers as Sponsor
2 Code for Use of Explosives in Coal Mines, with the Mine Inspectors Institute of America as Sponsor
3 Safety in Mine Transportation, with the American Mining Congress as Sponsor
4 Mine Illumination, with the Bureau of Mines as Sponsor.

Acting upon the report of another Special Committee the A.E.S.C. authorized the organization of a sectional committee to develop methods of testing textile materials. The A.S.T.M. was designated as the Sponsor and the following was approved as a scope of this project:

> Tolerances and test methods for cotton yarns and fabrics, such as those used in the rubber and electrical industries, numbered ducks, Army and tent ducks, fabric belting, sheeting, and other yarns and fabrics which may be subject to such methods of testing and tolerances.

The Standardization of Manhole Frames and Covers is now before the A.E.S.C. and is going forward under the sponsorship of the American Society of Civil Engineers and the Telephone Group. The scope of this project covers the design, material, and dimensional standardization, and it is further recommended that particular attention be given to the possibility of reducing the number of types and sizes in common use.

The report of the Special Committee dealing with the development of Standard Specifications for Steel Bridges was fully discussed. The Main Committee finally voted to refer the report on the organization of the sectional committee back to the special committee which framed it for further study and report.

The first report of the Sectional Committee on the Standardization of Shafting, which covers the diameters and lengths of cold-finished transmission and machinery shafting, was received and ordered to letter ballot of the Main Committee.

The scope and personnel of the Sectional Committee on the Standardization of Gears were approved.

The Committee also approved the recommendation of the Society

of Automotive Engineers and The American Society of Mechanical Engineers that a sectional committee be organized to review the work on the Standardization of Transmission Chains and Sprockets which a Joint Committee of the S.A.E., the A.G.M.A., and the A.S.M.E. began in July, 1917, and has now practically completed. It is probable that these three organizations will accept Joint Sponsorship under the A.E.S.C. Procedure.

The Portland Cement Centennial

MORE than a hundred years ago, on October 21, 1824, Joseph Aspdin, a bricklayer of Leeds, England, applied for a patent on a "method of making a cement or artificial stone for stuccoing buildings, water works, cisterns or any other purpose to which it may be applied, and which I call Portland Cement." The patent was granted to Aspdin the same year. Very fittingly in October of last year the American Portland Cement Association presented a commemorative tablet to the inventor at celebrations held jointly in Leeds with the British Cement Makers Federation.

A month later the American Association held a celebration in Chicago, at which many technical societies were represented. The addresses delivered at this celebration give a truly remarkable picture of the portland cement industry and its development.

The Romans understood the use of concrete, and their methods of pouring a semi-fluid mass of stones, lime, and pozzolana into a case of large and massive timbers were entirely successful. Such glorious structures as the Pantheon in Rome still stand as monuments to their skill. However, no substantial progress in the art of making cement was made until Aspdin's invention. His method was to make a mixture of clay and finely ground limestone, calcine it until the carbonic acid was expelled, and then grind the product to a fine powder. This resulted in a cement of far greater strength than the Roman product, and of a greater hydraulicity—particularly important in the maritime structures of sea-bound England.

Early manufacturers of portland cement feared vitrification of their product and actually threw out the clinker which approached the heat of incipient fusion. But it was not long after Aspdin—in 1845—that I. C. Johnson, of the famous White's British Cement works, found that his overburned clinker produced superior cement, and thereby laid the final foundations of modern methods of manufacture.

The first portland cement manufactured in the United States was produced by David O. Saylor at Coplay, Pa., although it was not until the early part of the twentieth century that American manufacturers attained the standing of foreign manufacturers in the matter of quality, while surpassing them greatly in quantity of output.

American civil engineers have been the boldest in applying reinforced-concrete construction to giant structures such as bridges and skyscrapers, and also in establishing the fundamental principles of design. Our mechanical engineers have not only used this material for the foundations of their prime movers and other machinery, but have also contributed greatly to improvements in manufacturing and handling it. They have improved the rotary kiln, with its long circular tubes of riveted steel reaching dimensions of 12 ft. in diameter and 200 ft. in length, lined with refractory brick, inclined to the horizontal about $^3/_4$ in. to the foot, rotated mechanically at 30 r.p.m., receiving the crushed raw material at the upper and slowly discharging it after calcination at the lower end. Mechanical engineers have also assisted in displacing the costly and slow methods of hand mixing by rapid and efficient mechanical mixers, with such adjuncts as storage bins, measuring hoppers, and automatic water regulators, giving a more accurate control of proportions. To distribute the output of a large mixer, trough-like chutes inclined at an angle of 23 deg. have been devised by mechanical engineers. The need for elevating concrete has brought into being special steel hoist towers with guides for running large concrete buckets, which are automatically tripped and discharge the concrete into barrows, carts, or chutes at any desired point. While chemists are still improving the composition of portland cement and civil engineers are planning more ambitious structures in reinforced concrete, mechanical engineers have a great field still before them in the further development of the mechanical equipment which is now in use on such a vast scale.

George Tilley Seabury New Secretary of A.S.C.E.

THE American Society of Civil Engineers announces the selection of George Tilley Seabury of Providence, R. I., to fill the office of secretary made vacant by the death of John H. Dunlap.

Mr. Seabury is a graduate in civil engineering from the Massachusetts Institute of Technology and has had long and varied experience in water-supply work with the Board of Water Supply of Providence and with the Board of Water Supply of New York City. During the war he served as major in the Construction Division of the United States Army, acting as supervising construction quartermaster in charge of construction at Camps Devens, Upton, Mills, Merritt, Dix, Meade, and Lee. As p esident and general manager of George T. Seabury, Inc., he engaged in general contracting business, specializing in road construction for about four years.

GEORGE TILLEY SEABURY

Since March, 1923, he has served as manager of the Providence Safety Council, which he has developed to an active organization of over four thousand members. His activities, which have included special publicity work, studies, analyses, and addresses, have been applied chiefly to reducing automobile accidents in Providence. His work has resulted in an accident decrease of twenty-one per cent in spite of the fact that there has been an increase in registered vehicles of twenty-five per cent.

Mr. Seabury takes up his duties with the A.S.C.E. early in the present month.

Comparison of Herbert Pendulum Hardness Tester with Other Hardness Testers—Errata

PROF. J. O. KELLER, author of the paper entitled Comparison of Herbert Pendulum Hardness Tester with Other Hardness Testers which appeared in the Mid-November, 1924, number of MECHANICAL ENGINEERING, writes that the figures in the column for the Rockwell ball test, Table 1, page 818, should read as follows:

A	100.3
B	96.8
C	90.2
D	94.3
E	103.1
F	97.6
AA	93.8

and that the figures for the Rockwell cone test should be omitted altogether.

On page 823, the second sentence of the last paragraph reads as follows: "The Brinell, Herbert time, Herbert scale, and scleroscope place C as the softest and the Rockwell ball test places D as softest." This sentence should be changed to read: "The Brinell, Herbert time, scleroscope, and the Rockwell ball test place C as the softest."

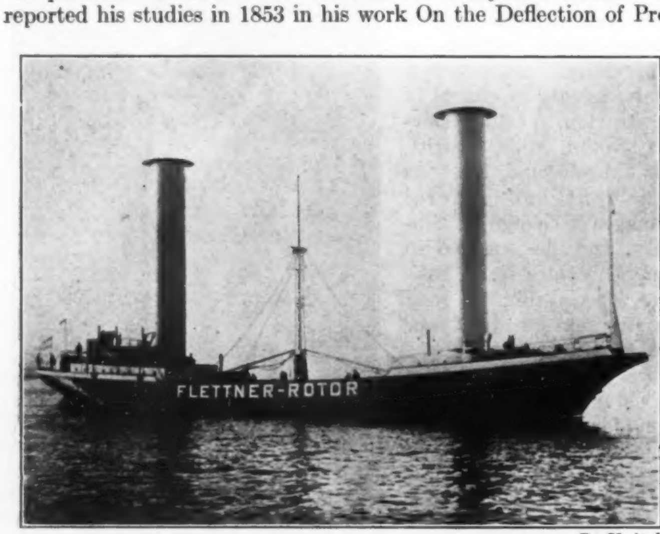
The reasons for these corrections, Professor Keller states, are that with all the hardness testers except the Rockwell, the data were obtained from the polished surface of the specimen. The Rockwell readings were taken from both the polished surface and

the rough outside scale of the specimens. The scale readings of the Rockwell were some ten points below the polished-surface readings of the Rockwell and should not have been averaged with the polished-surface readings.

The new figures given in the first paragraph are the Rockwell averages on the polished surface only, which gives a fair comparison with the other instruments. Since the Rockwell cone-test data were obtained from the rough scale only, all these readings should be omitted.

The Sailless Ship

WHY does a pitched baseball break sharply or a driven golf ball deviate from its path? Scientists may answer, the "Magnus effect," for it was Heinrich Gustav Magnus, professor of technology and physics at the University of Berlin, who studied the effect of wind on any rapidly rotating body and discovered the phenomenon with which his name is today associated. He reported his studies in 1853 in his work On the Deflection of Projectiles. Recently his principles have been employed by Herr Anton Flettner for the propulsion of his wind-power ship *Buckau*, Fig. 1, which has attracted a great deal of attention.



By United

Fig. 1 The "Buckau"—The Flettner Sailless Ship

Magnus discovered that a projectile set spinning by discharge from a rifle barrel became subject to the influence of a side wind as soon as its axis ceased to move exactly in the tangent to the trajectory and that the effect of the rotation was to give this side wind a transverse driving force, i.e., toward the side on which the relative speed of the wind and the circumferential speed were in the same direction. The Magnus effect is explained by the fact that a wind blowing against a rotating cylinder is so influenced that the friction of the cylinder surface draws the wind with it. Hence there follows a deflection of the off-flowing wind governed by the direction of rotation. In the vicinity of the cylinder surface where the direction of the wind and that of rotation are in accord, reduction of pressure results, while increase of pressure is set up in the reverse direction.

It would appear, therefore, that the low-pressure side is by far the more important, and special attention must be paid to the possibility of improving this decrease of pressure. The pressure distribution shown in Fig. 2 occurs when the ratio of wind velocity to circumferential speed is between 1:3 and 1:4. The distribution of pressure indicates approximately the results to be expected from the direction and force of the propulsive power derived from the Magnus effect when it is applied to the cylinder, and, therefore, to the ship on which the cylinder is erected. When determining the force of the driving power it was found to be very important to fit disks at each end of the experimental cylinder in order to prevent the counter pressure from escaping past the ends without having exerted its power. Such disks were accordingly fitted to the rotors of the *Buckau*. It was further ascertained that the driving power was dependent in very large measure on the relation between circumferential speed and wind velocity. When the relation is unity, wind pressure and propulsive energy are equal; when it is 2, the driving power is five times greater than the wind pressure, and it becomes nine times as great when the circumferential speed undergoes a four-fold increase of the wind speed; but from this point onward the ratio remains practically unaltered. Consequently, not even a hurricane would add much to the power of propulsion, for in that case the ratio between circumferential speed and wind velocity would approach unity. The driving power would thus be less even than that exerted by the masts and rigging of a sailing ship in a hurricane, while, on the other hand, the pressure exerted against the motionless cylinder would be considerably lower than the driving power. This result would have a most favorable effect on the stability and general behavior of the rotor ship in a storm.

Compared with the propulsive power of ordinary sails, that of the Flettner cylinder is about eight times as great, so that the surface area of the two cylinders need be only one-eighth that of a sail of corresponding value. Furthermore, the reduction in driving power caused by a change in the direction of the wind is much less with the cylinder than with sails. The *Buckau*, for example, can sail within about 30 deg. of the wind.

The reconstruction of the *Buckau* as a rotor ship was undertaken at the Germania yard, Kiel. The two driving towers, 15.6 m. (61 ft.) in height and 2.8 m. (9.2 ft.) in diameter, have covers of 1-mm. (0.04 in.) steel plate. Each is supported on a stout pivot, extending 1.5 m. (5 ft.) below and 13 m. (41.6 ft.) above the deck. They are operated by two reversible 220-volt direct-current motors each of 11 kw. capacity, driven by a 45-hp. Diesel engine. The stability of the ship was greatly improved by its reconstruction, for the heavy weights formerly carried high above deck level have gone, the built-in rotor towers being lighter and having a lower center of gravity. Hand wheels situated on the bridge control the direction and speed of rotation of both cylinders. When the forward tower ceases to revolve, the ship turns in the wind; tacking is effected by bringing the after tower to a standstill. To drive the ship ahead both towers are rotated clockwise from the windward side. When they are rotated in the opposite direction the ship goes astern. Turning and tacking maneuvers may be executed without causing the vessel to lose way—as she would do if under sail—for one of the towers still continues to drive her ahead. (Paper by Anton Flettner before the German Institution of Naval Architects, summarized in *The Engineer*, vol. 138, no. 3596, Nov. 28, 1924, p. 608, 1 fig., *d*)

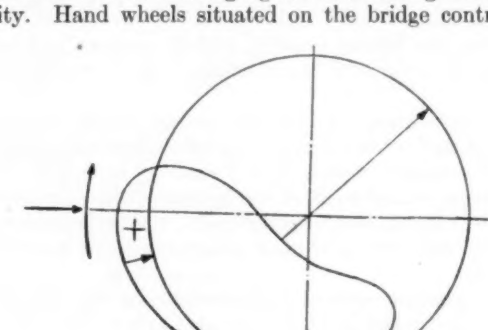


Fig. 2 The Magnus Effect

Index to Volume 46 of "Mechanical Engineering"

AN Index to Volume 46 of Mechanical Engineering is now in the course of preparation and, it is expected, will be issued early in February. A copy of this Index will be sent to each member of the Society or subscriber who sends in a written request therefor. Those who wish to receive an Index to Mechanical Engineering regularly each year may have their names entered upon a permanent list for that purpose upon application. In order that no more copies may be printed than are necessary to supply the demand, requests for copies should be received at headquarters not later than February 1.

Increased Compensation for Federal Judges Urged by A.E.C. Patents Committee

A REPORT of its Patents Committee, Edwin J. Prindle, Chairman, will be presented to the American Engineering Council at its Annual Meeting in Washington, D. C., January 16 and 17, 1925. The report, calling attention to the changed attitude of Congress and the Administration following previous campaigns for the Patent Office in which the American Engineering Societies effectually participated and which have resulted in the granting of one hundred additional examiners and increased space for the Patent Office in the Land Office Building, deals particularly with an immediate need of the patent system, namely, an increase in the salaries of the federal judges. The report says in part:

As the federal courts have sole jurisdiction of patents for inventions and of registrations for trademarks, the efficiency and welfare of these courts are of vital importance to the successful and beneficial administration of our patent system and federal trademark laws, and the question whether the salaries of the judges of those courts are adequate is one with which your Committee is therefore directly concerned.

For many years the salaries of the federal judges have been too low either to be fair to them or to be wise from the standpoint of efficiency of our federal courts. But the rise of the cost of living has now made it almost impossible for many of the judges to live upon their salaries, and some of the best of them have been forced to resign, while others are seriously considering doing so. This is particularly true of the judges in the more populous districts, where not only is the cost of living higher than in less populous districts, but the financial returns from private practice are so much higher as to make work upon the bench a greater sacrifice than elsewhere. Not only are the judges not fairly compensated, but they are unable to live and educate their children as is befitting their station and the high dignity of their office. These conditions are probably more important to the welfare of our patent system than to any other branch of the law, as few of the judges before appointment to the bench have practiced patent law or had contact with science, so that extended experience in deciding such cases tends to increase the facility with which they can do so. It is therefore a misfortune when a federal judge is obliged to leave the bench because of insufficiency of the salary, and it is of more concern to our engineers than to most other classes of our citizens to see that these salaries are made adequate.

That the salaries are inadequate will appear from the following statistics. The United States district judges receive \$7500 per annum; the United States circuit judges receive \$8500; the justices of the Supreme Court of the United States receive \$14,500, and the Chief Justice of the Supreme Court \$15,000 per annum.

In the supreme courts of the various states, salaries are paid which are higher than those paid to federal circuit and district judges, and which average as follows: Northeastern states, \$11,572; Atlantic, \$10,140; Northwestern, \$7,079; Southern, \$6,608; Southeastern, \$6,393; Pacific, \$6,113; and Southwestern, \$5,722. The average for 283 justices is \$7,701.

Bills having the approval of a committee of federal judges have been introduced into Congress as House Bill 9221, by Representative George S. Graham, Chairman of the Judiciary Committee of the house of Representatives, and Senate Bill 3363, by Senator David A. Reed, of Pennsylvania. These bills provide for raising the salary of the Chief Justice of the United States to \$20,500, the salaries of the associate justices of the Supreme Court to \$20,000 and the salaries of the circuit judges, according to the population of their districts, to \$13,000, \$14,000 or \$16,000. These bills also provide salaries for the United States district judges of \$10,000, with the provision that if the population of a district exceeds 2,000,000, the salary of a judge of that district may be increased \$500 for each 100,000 in excess of that sum. The salaries of the judges of the Court of Appeals of the District of Columbia and of the Court of Customs Appeals are raised to \$15,000, and the judges of the Court of Claims and of the Supreme Court of the District of Columbia are raised to \$13,000. The differential in favor of the salaries in the more populous districts is considered necessary because the cost of living is higher there and the compensation for private practice at law is also higher.

While our federal judicial system is one of the three great branches of our Government, its cost is truly insignificant. The difference between adequate salaries for the United States judges and the present inadequate ones would amount to not more than half a cent annually to each inhabitant of the United States. There should be, therefore, no hesitation nor any fear that the country cannot afford it.

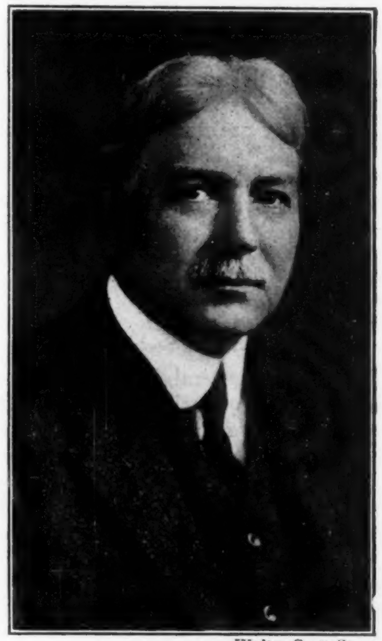
No matter how conscientious a judge may be, it is impossible for him to have as high an average of clear, penetrating thought in deciding the many intricate and important questions which come before him if his living and that of his family are inadequately provided for, as if his mind is reasonably free from financial care. The loss to the public through avoidable mistakes or failure to think clear through a problem under these conditions must be vastly greater than the cost of the proper salaries.

The National Association of Manufacturers, at a great deal of trouble and expense, played an exceedingly important part in the legislative campaign to raise the salaries of the Patent Office examiners. As the federal courts administrate the patents, it is equally desirable that the federal judges be properly paid. Your Committee believes that, with the same hearty coöperation which the Societies gave in the Patent Office campaign, the bills for raising the judges' salaries can be made a law, and it hopes that the American Engineering Council will adopt its suggestions and successfully perform another important public service.

Your Committee therefore earnestly recommends that it be given authority to help bring about the enactment of the before-mentioned bills, or other suitable bills to secure adequate salaries for the federal judges, and to that end to appeal to the membership of the Federated American Engineering Societies for aid.

John Lyell Harper, Well-Known Hydroelectric Engineer, Dies

JOHN LYELL HARPER, chief engineer and vice-president of the Niagara Falls Power Co., died on the morning of November 28, 1924, at the Memorial Hospital, Niagara Falls, after undergoing an operation for appendicitis four days earlier. Mr. Harper's work in the development of Niagara Falls power made him a national figure in hydroelectric engineering. He was associated with the Niagara Falls Power Co. and its predecessor, the Hydraulic Power Co., for 22 years, starting as assistant engineer. Under his leadership the plant grew from one of 14,000 hp. to one that today contains nearly one-half million horsepower under one roof, the largest installed capacity in any power plant in the world.


Walter Scott Shinn
JOHN LYELL HARPER

Mr. Harper was born in Harpersfield, N. Y., on September 21, 1873, and his boyhood was typical of the country lad on the farm. At twenty he was graduated from Stamford Seminary, and four years later from Cornell University with the degree of mechanical engineer. Upon his graduation he went west as a draftsman with the Oregon Improvement Co., Seattle, Wash. Four months of that work brought him a place with the Union Electric Co. of Seattle in the electrical field. In June, 1898, he was made operating and construction engineer of the Twin City Rapid Transit Co., and this brought him in contact with the work which was to make him a national figure in engineering.

It was in 1902 that Mr. Harper became associated with the Niagara Falls Hydraulic Power & Manufacturing Co., as assistant to the engineer, Wallace C. Johnson. From that time until his death his life is the romantic story of Niagara power. After two years he became chief engineer of the company. During the year 1918 the various power interests were grouped under Government direction into a new corporation taking the name of the Niagara Falls Power Co., and Mr. Harper was made its chief engineer. Upon the completion of the wartime power plant he was appointed vice-president of the company. The most famous power development in the world from the standpoint not only of engineering but of service is situated in the gorge below the falls of Niagara. It stands as a monument to the genius of John Lyell Harper.

Mr. Harper was also vice-president and chief engineer of the Harper-Taylor Co., consulting engineers. In spite of the many responsibilities with which Mr. Harper was burdened he found time to carry on scientific investigations of the applications of electric service in the electrochemical and the electrometallurgical industries at Niagara Falls and developed and patented several electric furnaces. He became a member of The American Society of Mechanical Engineers in 1906. He belonged also to the American Society of Civil Engineers, the American Institute of Electrical Engineers, the American Electrochemical Society, the American Ceramic Society, and the Engineers' Club of New York City.

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Books Received in the Library

A.S.T.M. Tentative Standards, 1924. American Society for Testing Materials, Philadelphia, 1924. Cloth and paper, 6 × 9 in., 763 pp., illus., diagrams, tables, $8.00, cloth; $7.00, paper.

"Tentative standards" are proposed standards which are printed by the Society for one or more years, in order to elicit criticism, before they are finally revised and recommended for adoption as "standards." The 1924 edition contains 185 tentative specifications, methods of testing and revisions of standards, covering a great variety of commercial products and materials, such as metals, cement and clay products, preservative coatings, lubricants, road materials, fuels, timber, insulating materials, boxes, textile materials, rubber products, etc.

Applied Elasticity. By John Prescott. Longmans, Green & Co., London and New York, 1924. Cloth, 6 × 9 in., 666 pp., $8.

This is, in general, a treatise on the theory of elasticity, but the author has approached the subject from the point of view of the engineer rather than from that of the mathematician and has developed this theory only so far as it seemed likely to lead to the solution of practical problems. In furtherance of this purpose, only problems of practical interest have been chosen to illustrate the theory, and approximate methods based on the principle of minimum energy have been used in the consideration of such problems as those of stability and of periods of oscillation. A number of results are published for the first time. These include methods for the deflection of a thin plate under normal pressure when the stretching of the middle surface is taken into account, an approximate method for the buckling loads of deep beams, and a method for the vibrations of a disk of variable thickness.

Chapter in American Education; Rensselaer Polytechnic, 1824–1924. By Ray Palmer Baker. Charles Scribner's Sons, New York, 1924. Cloth, 5 × 8 in., 170 pp., $1.

A brief, interesting account of the main points in the development of Rensselaer Polytechnic Institute, during its hundred years of existence, in which the national significance of its pioneer work is emphasized and attention is called to its influence on the development of scientific education and research in America, through its curricula and its alumni.

Combustion. By Industrial Gas Section of the American Gas Association. N. Y., American Gas Association, New York, 1924. Paper, 9 × 11 in., 74 pp., diagrams, tables, $1.50 to members; $3 to non-members.

This book has been prepared by the Association for its members who are interested in furthering the industrial applications of gas. It discusses the measurement of heat, the chemistry of combustion, calorimetry, thermal capacity, flame temperature, the analysis of furnace gases, recuperation, regeneration and the factors that affect the efficiency of utilization of gaseous fuels. The book is a summary of accepted practice and theory, based on standard texts and arranged conveniently.

Commerce Yearbook, 1923. By U. S. Bureau of Foreign and Domestic Commerce. Washington Government Printing Office, 1924 Cloth, 6 × 9 in., 722 pp., tables, $0.85.

The Commerce Yearbook is designed for business men, bankers, economists and students of national affairs who have use for a review of the economic year throughout the world from the viewpoint of American industry and commerce. It is based on the most reliable information available to the Bureau and is a mine of general information on the production, prices and movements of basic commodities and industries, on exports and imports and on trade conditions in other countries. The price of the book is absurdly low for the value of its contents.

Compressed Air Data. By William L. Saunders. Second edition Compressed Air Magazine, New York, 1924. Fabrikoid, 4 × 7 in. 290 pp., illus., diagrams, tables, $3.

A collection of formulas and data essential to an understanding of the theory of air compression and the engineering applications of compressed air. It is confined to information required by users of pneumatic machinery and does not discuss details of design or construction. The new edition has been revised, recent developments in the use of compressed air have been incorporated, and performance data and statistics of recently developed pneumatic tools have been added.

Elements of Machine Design. By S. J. Berard and E. O. Waters. D. Van Nostrand Co., New York, 1924. Cloth, 6 × 9 in., 323 pp., illus., diagrams, tables, $2.50.

Designed to fill the gap between engineering drawing and advanced machine design. Intended for students in technical schools and for young draftsmen preparing themselves as designers. The authors believe that success in designing machinery depends on the mastery of a few fundamental principles of mechanics, mechanism, strength of materials and the technique of drafting, and the coördination of these with a well-trained sense of proportion. They have therefore aimed at a logical, consistent development of approved methods of design, applied to the more common elements of machine construction.

Eye Hazards in Industrial Occupations. By Louis Resnick and Lewis H. Carris. National Committee for the Prevention of Blindness, New York, 1924. Paper, with linen backing, 6 × 9 in., 247 pp., illus., tables, $1.50; fabrikoid, $2.50.

This report, issued by the National Committee for the Prevention of Blindness, is the result of two years' study of eye hazards in industrial occupations and of methods for their elimination. It is a thorough review of the various diseases and accidents to which labor is exposed, of the approved safety devices and methods of shop lighting, and of safety practices in various companies. A list of references is included.

Gear-Cutting Processes. By Franklin D. Jones. Industrial Press, New York, 1924. Cloth, 6 × 9 in., 342 pp., illus., tables, $3.

This book describes commercial methods for cutting all ordinary types of gearing, including recent developments in gear cutting and tooth grinding. Specific information is given on the principles of gearing and on the methods of adjusting machines of different types. The use of standard milling machines for cutting gears is explained. Attention is also given to the relation between various machines and the classes of work for which they are adapted, and the commercial rates of production by different processes are given.

Kinetic Theory of Gases. By Eugène Bloch. E. P. Dutton & Co., New York, n. d. Cloth, 5 × 8 in., 178 pp., tables, $3.

The kinetic theory of gases is merely a branch of the molecular

theory of matter, but it is the most completely developed branch and the one in which reasoning and calculation can be most simplified. In the present book Professor Bloch outlines the principal mean properties that have been mathematically deduced from observed molecular motion and presents the principles of the theory in a clear manner. The mathematics has been simplified as much as possible. The book is intended as an introduction to the subject and includes a list of books for those who wish to pursue the subject further.

Lehrbuch der Nomographie. By H. Schwerdt. Julius Springer, Berlin, 1924. Boards, 6 × 8 in., 267 pp., diagram, 12.90 g.m.

A thorough textbook for serious students of nomography. While it has the primary purpose of introducing the student to practice in nomographic problems and acquainting him with the most important aids, it also pays attention to the connection of this branch of applied mathematics with its neighbors. The book develops the fundamental principles so that they may be applied and illustrates them by detailed application to important cases. Special attention is paid to accuracy in charts.

Measurement of Fluid Velocity and Pressure. By J. R. Pannell; edited by R. A. Frazer. Edward Arnold & Co., London, 1924. Cloth, 6 × 9 in., 135 pp., illus., diagrams, $3.50.

The author, who was killed by the fall of the British airship R-38 in 1921, had been engaged for many years in aerodynamic research and had devoted his leisure to the preparation of the present treatise, which he left practically complete. The book treats of the various types of instruments, pressure-tube, moving-part and hot-wire anemometers, direction and velocity meters, ship logs, and manometers which have been devised for measuring the velocity and pressure of fluids, and also contains a chapter on the laws governing the flow of fluids in circular pipes.

Power Plant Machinery, vol. 2; Details and Accessories. By Walter H. James and M. W. Dale. John Wiley & Sons, New York, 1924. Cloth, 6 × 9 in., 267 pp., illus., $3.

The second of two volumes, intended to form a connecting link between the study of mechanism and heat engineering, in which are generally discussed the principal machines used in a steam power plant, not including boilers, stokers, and machinery for handling coal and ashes. The present volume is largely descriptive. It gives in detail the construction of the various parts of reciprocating engines and treats of turbines, compressors, pumps, steering engines, reversing gears and steam and pneumatic tools. Various auxiliaries, such as feedwater heaters, condensers, cooling towers and spray ponds, together with such devices as pulsometers, air lifts and hydraulic rams, are also treated.

Recent Progress in Engineering Production. By C. M. Linley. Ernest Benn, London, 1924. Cloth, 7 × 10 in., 340 pp., illus., diagrams, 42s.

This book, of British origin, was written to place engineers, machinery manufacturers and users of machinery in touch with the latest developments and improvements in machine tools, works practice, manufacturing methods, processes and alloys. The improvements are mainly those that tend to reduce cost of production and at the same time produce a better article. Only developments that have passed beyond the experimental stage are considered.

La Soudure Electrique A L'Arc Métallique. By S. Frimaudeau. Gauthier-Villars et Cie, Paris, 1924. Paper, 5 × 7 in., 135 pp., illus., diagrams, 10 fr.

A concise handbook of practical information on methods of arc welding, on welding machines and on the theory underlying the process.

Structural Engineering; Strength of Materials. By George F. Swain. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 9 in., 569 pp., illus., diagrams, $5.

The present volume is the first of a series of four treating of the theory and design of structures, which will embody the course that the author has been giving for many years, with amplifications intended to make it a fairly complete treatise for engineers. It aims to give a clear, complete and simple discussion of the fundamental principles of the strength of materials applicable to the design of various kinds of structures, including masonry and concrete, as well as framed structures, and to occupy a middle ground between the brief textbooks and the encyclopedic works of reference. It goes beyond the limits of the curricula of most engineering schools and places the student in a position to pursue the subject further.

Thermodynamique. By J. A. Ewing. Translated by M. R. Duchesne. Gauthier-Villars et Cie., Paris, 1924. Paper, 6 × 9 in., 488 pp., diagrams, tables, 50 fr.

A French translation of Professor Ewing's Thermodynamics for Engineers. The original has been followed very exactly by the translator, but metric measures have been substituted for the English units in the various numerical tables.

Forty-Fifth Annual Meeting of A.S.M.E.

(Continued from page 69)

between the regular sessions of the program, often at breakfast or luncheon.

The regular quarterly meeting of the Main Committee on Power Test Codes was held on Monday morning and was attended by 27 members. The results accomplished by this meeting were principally of a routine nature, but recorded definite progress for the completion of the 20 codes begun by this Committee six years ago. In addition to the meeting of the Main Committee, six Individual Committees discussed details of the codes assigned to them. Individual Committee No. 6 on Steam Turbines had breakfast with Committee No. 12 on Condensers, Water Heating and Cooling Equipment to discuss the best place to measure the vacuum in the exhaust of a steam turbine and the intake of a condenser. Individual Committee No. 2 on Definition and Values reviewed the abbreviations and symbols of the entire group of Power Test Codes with the A.S.M.E. group of the Sectional Committee on Scientific and Engineering Abbreviations and Symbols at luncheon on Tuesday. The same day Committee No. 16 held a meeting on Gas Producers prior to the Public Hearing on that Code. The next day Committee No. 10 on Centrifugal and Turbo-Compressors and Blowers held a full meeting and went over the preliminary draft of this Code. This meeting was then merged into a meeting of the Special Committee on Velocity-Volume Measurements. That afternoon Committee No. 3 on Fuels talked over the results of the Public Hearing on the Code for Solid Fuels held the previous afternoon. A complete and generally satisfactory preliminary draft of the Test Code for Refrigerating Machines and Plants was fully discussed at the meeting of Individual Committee No. 13, which was held on Thursday afternoon.

Four of the research committees held meetings. The Special Research Committee on Metal Springs held its meeting on Monday afternoon. Later in the week the Committees on Gears and the Cutting and Forming of Metals held well-attended meetings. The Main Research Committee held a luncheon meeting on Thursday.

In the standardization group the following committees held meetings: A.S.M.E. Standardization Committee; Working Committee on Tee Slots of Sectional Committee on Standardization of Small Tools and Machine Tool Elements; Sub-Committee No. 2 on Methods of Gaging Manufactured Material of Sectional Committee on Plain Limit Gages for General Engineering Work; Technical Sub-Committee on Roller Transmission Chains; Sectional Committee on Identification of Piping Systems; and Sectional Committee on Safety Code on Machinery for Compressing Air.

The Committee on the Identification of Piping Systems discussed fully the report of its three sub-committees which had been previously mailed to all members. It then voted to instruct the secretary to mail revised drafts of these reports to the members for letter ballot. It is expected, therefore, that this Code, which will consist of a combination of these three reports, will be issued in pamphlet form early next spring.

The Committee on a Safety Code for Machinery for Compressing Air completed its organization by selecting Harry D. Edwards as permanent chairman and William C. Straub as permanent secretary. The plan and scope for this project was discussed and Dr. Allan D. Risteen was elected Chairman of a sub-committee to develop a satisfactory wording.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

LAST MINUTE ADDITIONS: MAIN BODY ON PAGE 137-EI., ADVERTISING SECTION

Exigencies of publication make it necessary to put the main body of The Engineering Index into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRSHIPS

Semi-Rigid, Construction. Building a Semi-Rigid Airship, J. Younger. Am. Mach., vol. 61, no. 23, Dec. 4, 1924, pp. 867–872, 20 figs. Design; manufacture of gas bag; use and fabrication of duralumin; assembling articulated keel; assembling pilot car.

AUTOMOBILES

Electric. The Electric Road Vehicle, D. E. Batty. Engineering, vol. 118, nos. 3072 and 3073, Nov. 14 and 21, 1924, pp. 688–692 and 719–720, 13 figs. Its characteristics and its economic field of usefulness. (Abstract.) Paper read before Instn. Automobile Engrs.

BALLS

Hollow Seamless, Manufacture. Hollow Seamless Balls, F. D. Jones. Machy. (N. Y.), vol. 31, no. 4, Dec. 1924, pp. 255–260, 10 figs. How seamless balls are made from single piece of metal; rolling operation, which follows press work, is important step in process, patented by Hollow Ball Co., Baltimore, and developed to insure accuracy of form and balance, combined with lightness and strength. See also description in Iron Age, vol. 114, no. 24, Dec. 11, 1924, pp. 1544–1545, 5 figs.; and description, by F. Dantzig, in Am. Mach., vol. 61, no. 23, Dec. 4, 1924, pp. 877–880, 6 figs.

BEARINGS, BALL

Roller and. Swedish Disk and Ball Bearings of High Carrying Capacity. Automotive Industries, vol. 51, no. 22, Nov. 27, 1924, pp. 918–919, 5 figs. Describes ball and roller bearings of Swedish manufacture, known as N.K.A., said to possess unusually high carrying capacity for given size and to be well adapted for high speed.

BEARINGS, ROLLER

Manufacture. The Manufacture of Tapered Roller Bearings, M. T. Lothrop. Am. Mach., vol. 61, nos. 21 and 22, Nov. 20 and 27, 1924, pp. 803–807 and 833–837, 31 figs. Nov. 20: Practice at Timken roller-bearing plant; continuous process from ore pile to finished product; uniform control of material processes, assembly, installation and use; grinding and inspecting to quarter-thousandth limits. Nov. 27: Hardness tests; inspecting 39 types of defects; automatic machines for grinding and gaging.

BOILER FURNACES

Air Preheaters. Air Preheaters and Their Application. Power, vol. 60, no. 23, Dec. 2, 1924, pp. 884–889, 10 figs. Summary of conditions which lead to interesting sidelights on preheating of air; describes types of air preheaters.

BOILERS

Waste-Heat. Good Results from New Type Fire-Tube Waste-Heat Boilers in Open-Hearth Plant. Power, vol. 60, no. 22, Nov. 25, 1924, pp. 832–834, 3 figs. Bettendorf Co., manufacturer of railway cars and material, has installed six waste-heat boilers of high-velocity, single-pass, fire-tube type of new design; results of 8-hr. tests; exceptional economies attributed to straight flow and high gas velocity in relatively small tubes; scrubbing action of gases keeps surface clean, and strong agitation results in high heat transfer.

BOLTS

Standardization. International Standardization of Bolts and Nuts. Machy. (N. Y.), vol. 31, no. 4, Dec. 1924, p. 314. Account of conference held in New York under auspices of Am. Eng. Standards Committee at which representatives of German, Czecho-Slovakian and American national standardizing bodies were present.

BONUS SYSTEMS

Foremen. Making a Bonus System Pay Dividends, A. W. Rowley. Indus. Mgt. (N. Y.), vol. 68, no. 6, Dec. 1924, pp. 357–361. Describes design and operation of bonus system which encourages coöperation between foremen; consists of production, cost-reduction and suggestion bonus.

CENTRAL STATIONS

Tennessee. Hales Bar Steam Plant on the Tennessee River, L. R. Lee. Power Plant Eng., vol. 28, no. 23, Dec. 1, 1924, pp. 1178–1182, 4 figs. Constructed adjacent to 45,000-kw. hydroelectric plant where it has been possible to take advantage of many existing facilities; coal is brought to plant by barges; economizer soot pits connected to boiler ash pits; steam can be extracted from three stages.

CHAIN DRIVE

Silent. The Application of Silent Chain Drive to Machine Tools, Chas. R. Weiss. Am. Mach., vol. 61, no. 23, Dec. 4, 1924, pp. 873–876, 8 figs. Development and characteristics of bushed silent chain; advantages of silent-chain drive; application to machine tools; principles of automatic chain tightener.

COAL HANDLING

Equipment. How Mechanical Handling Cuts Power Costs, M. W. Potts. Indus. Mgt. (N. Y.), vol. 68, no. 6, Dec. 1924, pp. 341–348, 14 figs. Describes types of coal and ash-handling equipment.

Low-Cost System. Low Cost Handling of Coal and Ashes, F. Schultz. Mgt. & Administration, vol. 8, no. 6, Dec. 1924, pp. 623–626, 8 figs. Describes system suited to industrial power plants.

COMBUSTION

Control. Use of Combustion Control Devices Increases, R. J. S. Pigott. Power Plant Eng., vol. 28, no. 23, Dec. 1, 1924, pp. 1199–1203, 4 figs. Three principles for controlling ratio of air to fuel; classification of commercial systems; connection of regulator to control valves; connection to dampers or rheostats; opportunities for central control.

CUPOLAS

Charging. Mechanical Charging for a Foundry Cupola. Iron Age, vol. 114, no. 22, Nov. 27, 1924, pp. 1397–1398, 3 figs. More uniform mixing and better iron are secured; hydraulic core remover cuts costs of cleaning castings.

DIESEL ENGINES

Preheating Fuel Oil. Preheating Fuel Oil for Diesel Engines, Rob. A. Melrose. Power, vol. 60, no. 23, Dec. 2, 1924, p. 904. Discusses methods.

DROP FORGING

Drop Stamps. Drop Stamps with Multiple Impression Dies. Engineering, vol. 118, no. 3073, Nov. 21, 1924, pp. 705–706, 2 figs. Describes battery of drop stamps introduced by Brett's Patent Lifter Co., to be used for production of parts of railway appliances; novelty of installation consists in arrangements made for use of multiple-impression dies.

EMPLOYMENT MANAGEMENT

Central Stations. Power Plant Personnel, K. W. Stillman. Mgt. & Administration, vol. 8, no. 6, Dec. 1924, pp. 633–636, 5 figs. Selection, training, and promotion of steam-power-station employees.

FLOW OF AIR

Around Cylinders. The "Magnus" Effect. Engineer, vol. 138, no. 3595, Nov. 21, 1924, p. 589, 5 figs. Discusses nature of Magnus effect which is alleged to be employed by A. Flettner for propulsion of his wind-power ship "Buckau."

FOUNDRIES

Decentralized Control. Organization for Better Foundry Practice. Iron Age, vol. 114, no. 24, Dec. 11, 1924, pp. 1552–1554, 2 figs. One man vs. decentralized control; analysis of business before changing to decentralized control; successful one-man operation and its limitations.

GAS TURBINES

Holzwarth. Development of Gas and Oil Turbines. Iron Age, vol. 114, nos. 21 and 22, Nov. 20 and 27, 1924, pp. 1329–1333 and 1407–1409, 13 figs. Nov. 20: Use of intermittent impulses found to give results where continuous impulse method failed; unit developed by Holzwarth for steel-works use. Nov. 27: Test data showing efficiencies obtained; estimated capital and operation costs; study of charted efficiency curves.

GEARS

Testing. Testing and Adjusting Spiral Bevel Gear Drives for Automobiles. Am. Mach., vol. 61, no. 22, Nov. 27, 1924, pp. 848–849, 14 figs. Printed by permission of The Gleason Works, Rochester, N. Y.

GRINDING MACHINES

Cylindrical. New Cylindrical Grinding Machine Will Load, Grind and Eject Parts Automatically. Automotive Industries, vol. 51, no. 23, Dec. 4, 1924, pp. 973–974, 2 figs. In new Arter machine, parts are loaded into turret mechanically or by hand, moved to grinding position by indexing, ground by straight infeed of wheel and then ejected.

INDUSTRIAL MANAGEMENT

Budgeting. Industrial Budget Methods, J. H. Barber. Mgt. & Administration, vol. 8, nos. 4, 5 and 6, Oct., Nov. and Dec., 1924, pp. 371–376, 479–486 and 589–594, 27 figs. Oct.: Explains methods of scientific forecasting and shows results that can be attained. Nov.: Methods of quantitatively analyzing particular cycles (of orders, shipments, collections, etc.) of particular business. Dec.: Forecasting underlying cycles.

INDUSTRIAL PLANTS

Location. Economic Factors in Industrial Plant Location, P. F. Walker. Mgt. & Administration, vol. 8, nos. 3 and 6, Sept. and Dec. 1924, pp. 259–264 and 637–642, 1 fig. Sept.: Discusses influence of country's growth; development of transportation centers; national industrial system; proposals for remedying conditions; results of modified rate structure; effects of present rate structure; factors which influence location; basis for estimating demands; process of organization; importance of products to location; etc. Dec.: Importance of adequate water supply; distribution cost analysis; shifting of industries.

LATHES

Turret. Normal Capacity of Turret Lathe Increased, L. S. Love. Iron Age, vol. 114, no. 24, Dec. 11, 1924, pp. 1529–1531, 7 figs. Offset chuck jaws effect nearly double production; combining operations improves quality of product.

LOCOMOTIVES

Diesel-Electric. A Diesel-Electric Locomotive. Engineer, vol. 138, no. 3594, Nov. 14, 1924, pp. 552–554, 5 figs. Results of trials at Esslingen Engine Works, Stuttgart, Germany, where locomotive, designed by Geo. Lomonossoff, was constructed.

Internal-Combustion. Crude-Oil Engine Shunting Locomotive. Engineering, vol. 118, no. 3073, Nov. 21, 1924, pp. 701–703, 10 figs. Locomotive constructed by Swiss Locomotive & Machine Works, Winterthur, Switzerland, is built for standard gage; engine works on 4-stroke cycle and utilizes airless injection for fuel.

MACHINE TOOLS

Automotive Industry, Influence of. How the Automotive Industry Has Influenced the Design of Machine Tools, A. L. De Leeuw. Am. Mach., vol. 61, no. 23, Dec. 4, 1924, pp. 891–892. Pre-automobile influences, such as steam engine, interchangeability, high-speed steel and electric motor; effects brought about directly by automotive industry.

MECHANISMS

Intermittent-Motion. Intermittent Motion Mechanism, A. W. Harris. Machy. (N. Y.), vol. 31, no. 4, Dec. 1924, pp. 301–304, 6 figs. Describes intermittent movement which is not only of rotary type, but will give any variation of intermittent motion that may be required; design for starting one mechanism the instant another stops; arrangement for prolonged rest periods; application to automatic machine.

SCRAP

Briquetted Chips as. Using Briquetted Chips as Furnace Scrap. Iron Age, vol. 114, no. 24, Dec. 11, 1924, pp. 1537–1538, 4 figs. Compressed material turned out by machine of $6^1/_2$ tons capacity per hr. at steel plant of Timken Roller Bearing Co., Canton, O.; method of gathering chips.

STEAM POWER PLANTS

Equipment. Savings Produced by Power Equipment, Geo. E. Hagemann. Mgt. & Administration, vol. 8, no. 6, Dec. 1924, pp. 627–630. Experience data from typical industrial plants; notes on steam-flow meters; boiler-room meters; oil purifiers.

Heat-Head Utilization. The Utilization of Heat Head, A. G. Christie. Power, vol. 60, no. 23, Dec. 2, 1924, pp. 892–893. In case of high pressure and highly super-heated steam heat head may be considered as heat available from adiabatic expansion from initial conditions at superheater outlet down to final exhaust pressure or vacuum; heat head for any conditions can be readily found from Mollier diagram; utilization of continuous blowdown.

STEAM TURBINES

Performance Tests. Tests on a Richardsons, Westgarth and Co.'s Steam Turbine. Engineering, vol. 118, no. 3072, Nov. 14, 1924, pp. 668–669. Particulars of tests carried out periods extending over three years.

STEEL CASTINGS

Aluminum and Titanium as Deoxidizers. Aluminum and Titanium as Deoxidizers, Geo. F. Comstock. Iron Age, vol. 114, no. 23, Dec. 4, 1924, pp. 1477–1479, 10 figs. Comparative effect on acid electric steel castings; physical and photomicrographic results.

STEEL WORKS

Improvements in Equipment. Mill Combination Increases Yield, J. D. Knox. Iron Trade Rev., vol. 75, no. 23, Dec. 4, 1924, pp. 1493–1496 and 5100, 7 figs. Improvements at steel works of United Alloy Steel Corp., Canton, O., involved rearrangement of rolling mills, enlargement of blast furnace and installation of steam-generating equipment.

STOKERS

Planning Installations. Planning Modern Stoker Installations, Jos. G. Worker. Blast Furnace & Steel Plant, vol. 10, no. 12, Dec. 1924, pp. 559–561, 7 figs. Résumé and analysis of combustion problem; includes review of modern stoker installations.

SUPERHEATED STEAM

Regenerative Feed Heating by. Regenerated Feed Heating by Superheated Steam, Thos. B. Morley. Engineer, vol. 138, no. 3594, Nov. 14, 1924, pp. 544–545, 2 figs. Author seeks to demonstrate fallacy of statement that use of superheated steam extracted from higher pressure stages of turbine for feed heating is essentially uneconomical on purely thermodynamic grounds; discusses process of regenerative feed heating in general with reference to steam-turbine plant.

SUPERPOWER

Interconnection, Southeastern States. Interchange of Power in the Southeastern States, J. M. Oliver. Iron & Steel Engr., vol. 1, no. 11, Nov. 1924, pp. 573–575, 5 figs. Virtual super-power system has been in existence in South for several years covering Alabama, Georgia, Tennessee, North and South Carolina; consists of interconnected systems of seven independent companies.